

STRUCTURAL CONDITION REPORT

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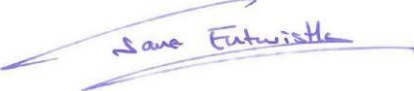
Museum of Science and Industry
Air and Space Hall
Liverpool Road
Manchester
M3 4FP



for

Allied London
7-8 Savile Row
London
W1S 3PE

Contract No: 11112
Dated: March 2022

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THOMASONS

CONTENTS

1.0 Introduction

2.0 Scope of Report

3.0 General Description

4.0 External Observations

5.0 Internal Observations

6.0 Discussions and Conclusions

7.0 Recommendations

APPENDIX A Structural Defect and Repair Schedule

APPENDIX B Manchester Association of Engineers; An Illustrated Talk on The Conversion Of The Victorian City Hall Into The Air & Space Museum

1.0 INTRODUCTION

1.1 Thomasons was instructed by Ted Hewins of London Allied Ltd, to undertake a visual inspection and report of the structural condition of Lower Campfield Market Hall, currently occupied by the Science and Industry Museum Air and Space Hall, Liverpool Road, Manchester. Representatives of the practice visited the property on 24 February 2022. The Science and Industry Museum provided access to the Air and Space Hall for the purpose of the inspection.

1.2 The weather at the time of the inspection was cold and overcast with occasional rain and snowfall.

2.0 SCOPE OF REPORT

2.1 The purpose of the inspection was to conduct a non-intrusive visual survey of all structural elements of the building.

2.2 The inspection was conducted from ground level to the internal and external elevations of the structure. The existing gallery walkway at first floor was utilised to inspect the roof construction and upper portions of the columns. The external roof covering was not included in the survey.

2.3 The external fabric was inspected from ground level to the front, on Liverpool Road, left and righthand elevations, from Lower Byrom Street and Byrom Street, respectively. The rear of the property was inspected from the pedestrian footpath between Lower Byrom Street and Byrom Street. The external fabric was largely obscured by the temporary hoarding and scaffolding erected to all external elevations of the property.

2.4 This report records the visible defects and comments on the severity of the defect in terms of recommended repair and the timescales which such repair should be undertaken. Areas for further investigation are also outlined. A schedule of the defects and recommended repairs is included in Appendix A of this report

2.5 The Lower Campfield Market Hall is a grade II listed building and the Historic England listing for the property reads as follows

2.6 LIVERPOOL ROAD (North side), Museum of Science and Industry, Air and Space Museum

MANCHESTER

SJ8397NW,

698-1/30/217

(Formerly Listed as: LIVERPOOL ROAD (North side) City Exhibition Hall)

17/05/74

GV

Grade: II

Formerly known as: Lower Campfield Market LIVERPOOL ROAD. Market hall, now museum. 1876, by Mangnall and Littlewood. Cast-iron and wood with slate and glass roofs. Large rectangular plan in the form of a nave with north and south aisles under parallel roofs, and north and south transepts to the centre and both ends. Two storeys, 1:3:1:3:1 bays, the centre and ends gabled, and the centre both wider and higher. Cast-iron columns with crocket caps, each bay divided horizontally by a moulded cornice, with small columns and decorated cast-iron railings below this and large-paned glazing above. The centre has a tall segmental-headed doorway rising into the glazed upper portion, a latticed band above eaves level, the gable filled with round-headed lights with slender shafts and margin panes, a bracketed cornice and the gable end of a continuous louvred ventilator, with a finial. Each end bay has a segmental-arched open-work panel in the centre, and an elliptical-arched iron bressummer to the gable, with glazing like that of the centre. The intermediate bays have oversailing eaves with scallop fringes, and continuous ridge ventilators. Three-bay east and west ends in matching style. Interior: cast-iron pillars with decorated caps carrying latticed girders, slender elliptical-arched latticed roof girders. Forms group with former Higher Campfield Market Hall to east (q.v.), by same architects in very similar style.

Listing NGR: SJ8327097786

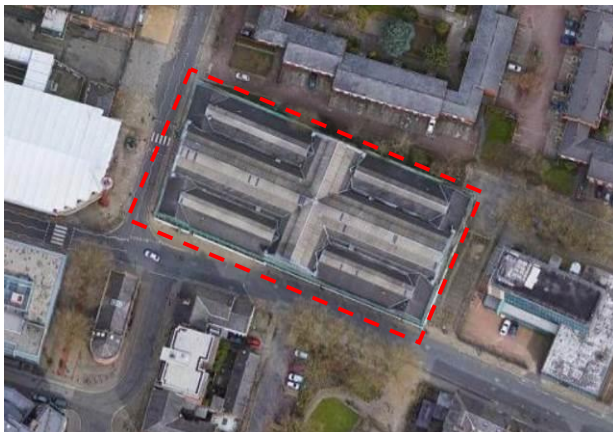
3.0 GENERAL DESCRIPTION

3.1 All observations are made as the property is viewed from, Liverpool Road, located to the south of the property, unless noted otherwise.

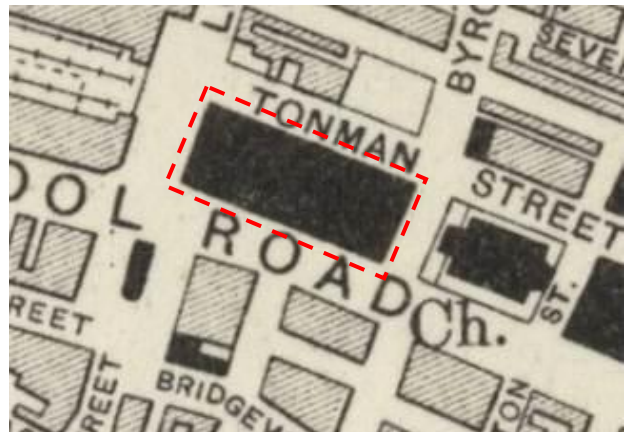
3.2 Lower Campfield Market Hall comprised a Victorian era former open sided market hall originally constructed in the 1880s. The hall comprised 35' wrought iron arched trusses spanning between regularly spaced cast iron columns. The overall layout was of two main aisles extending in both north-south and east-west directions forming a cruciform arrangement with a crossing point at the centre of the building. To the north and south sides of the longitudinal aisles there were additional side aisles. The centre area of the cruciform formed a large, vaulted area of diagonal trusses supported by the four main square columns located at the ends of each aisle. Secondary columns along each aisle were circular and of a smaller diameter than the primary central columns.

3.3 The roof of the structure comprises mineral fibre slate tiles on timber battens spanning between timber purlins in turn supported by the wrought iron trusses. The original roof covering is thought to have been natural slate, later changed to the mineral fibre slates to reduce the weight of the roof.

3.4



Googlemaps: aerial view of Lower Campfield Market Hall, Liverpool Road, Manchester



Maps.nls.uk – OS Six Inch, 1888-1913

- 3.5 Wrought iron lattice trusses spanned between columns heads parallel to, and along the support lines of, the main aisles. The lattice trusses comprised back to back angles with cross braced lattice plate sections between rivetted to a top and bottom plate.
- 3.6 The roof structure of the side aisles comprised wrought iron raised tie scissor trusses spanning between lattice trusses spanning from front to rear and from side to side and the external frame columns. The roof construction of the ends of the side aisles of the structure similarly comprised raised tie scissor trusses spanning in a perpendicular orientation to the aisle roofs.
- 3.7 The columns of the aisles were of cast iron and typically of circular cross-section tapering from the bottom up to roof level. The central columns at the intersection of the aisles were square and of a greater cross section than the aisle columns.
- 3.8 Historic remedial works had been undertaken to the structure. The main intervention was undertaken in the 1980s; this included the installation of tie rods between the springing points of the ached lattice trusses to the centre aisles. Additionally, a ridge beam had been introduced between side aisle trusses to provide lateral stability to the top chord of those trusses. The first floor gallery was originally constructed circa 1900 and was reconstructed with an additional cantilever some ten years later. It was during the 1900 works that the sides of the building were infilled.
- 3.9 The external elevations of the property typically comprised high level glazing in timber framing spanning between lattice wrought iron lattice trusses supported by external columns and a propped cill beam spanning between columns. The props to the cill beam comprised smaller cast iron columns with a similar ornate floral motif to the upper capital and a central rose motif in the centre of each column. At ground level a small upstand was present between the lower level columns which apparently once supported metal railings.
- 3.10 The main entrances from Liverpool Road to the south of the property, and the side entrance on Lower Byrom Street, to the left of the property, had been temporarily dismantled and enclosed at the time of the inspection. The temporary removal of the two entrances was to facilitate the decant of the existing museum including planes and other aviation paraphernalia. The scaffolding erected to the external façade of the structure temporarily enclosed these two entrances with a large roller shutter door introduced to the Liverpool Road elevation.

4.0 EXTERNAL OBSERVATIONS

- 4.1 The observations included below are general to provide an overview of the structural condition of the building. The detailed list of defects is included in the schedule in Appendix A of this report.
- 4.2 The external elevations of the property and the protections applied to the structure were in varying states of disrepair and a degree of remedial works had been historically introduced.
- 4.3 Loss of paint protection and surface corrosion was observed to the majority of the circular and square column heads. The upper columns heads were also noted to exhibit extensive pitting with rust staining affecting the majority of the external columns particularly around the joints and base of each column capital. The corrosion in these areas had led to a minor loss of section and definition of the ornate detailing works to the capitals of each column. This typically affected the floral decoration at the head of the capital and the rose motif projecting from the outside face of each column.
- 4.4 The existing hoarding erected to Liverpool Road, Lower Byrom Street and Byrom Street obscured the view of the base to the majority of columns on those elevations.
- 4.5 The wrought iron trusses on the external elevation had been historically strengthened with the addition of mild steel haunch stiffeners back to the supporting columns. Corrosion was observed between the plates of the connections at either end of the lattice trusses where the more modern mild steel haunches had been installed. The corrosion may have occurred due to bi-metallic corrosion or water becoming trapped between the metal plates. Surface corrosion and minor delamination of the interface between the two materials was observed to each truss where not obscured by the external hoarding.
- 4.6 A decorative crest motif was observed to the base and head of each square column to the perimeter of the property. Typically, each crest was present to both the base and top of each column however the top motif to the rear lefthand corner column of the structure was missing and a void in the face of the column remained where the motif would have been. The surrounding metal work to the missing crest was rust stained where water ingress has occurred.
- 4.7 A large amount of bird droppings was recorded to the rear elevation to the pedestrian route between Lower Byrom Street and Byrom Street to the upper columns and external lattice trusses

to the underside of eaves. The wrought iron trusses located below eaves level of the property appeared to be used as roosting locations.

4.8 The timber window frames typically appeared to be in a reasonable condition with local staining of the external surface where abutting the cast iron columns and iron trusses.

4.9 The capital of each column was generally in a reasonable condition with local defects recorded to each. Typically, the defects included rust staining to the lower portions and between the joints of the capital sections, surface corrosion and pitting of the capital was observed to the majority of columns and local fractures or loss of parts of the capital were observed in isolated cases. It was unclear from the survey if any of the column capitals were loose and at risk of falling from the building façade.

4.10



General view on front elevation from Liverpool Road



General view on rear elevation from Byrom Street

4.11



Corrosion and surface pitting to column capitals



Rust staining and surface corrosion to column head and upper capital

4.12



Isolated loss of part to column capital



Missing decorative crest to the upper portion of the rear lefthand corner column

5.0 INTERNAL OBSERVATIONS

5.1 It was apparent that the internal columns, supporting the roof structure, were inclined outwards from their original positions both across the width of the structure and along the length of each side aisle tending towards the perimeter of the property. Measurements of the columns could not be established during the visit due to the taper of the heads of the columns however similar historical distortions were recorded to the Upper Campfield site located on Barton Street, a structure with a similar form of construction and constructed in 1878. The level of distortion of the columns were not considered to be of such a degree to be regarded as unsafe, and the installation of ties between the bottom chords of the arched trusses were understood to have been installed to resolve the matter. Historically, ties were also intended to be installed between the springing points of the diagonally spanning trusses to the centre of the structure. These ties had not been installed although the fixing points were installed to the base of each truss.

5.2 The columns were all adorned with a decorative capital detail. Each capital comprised non-structural cast iron sections bolted to the tops of the columns. Three rose motifs were present at the head of each circular and square column. The central rose of the pattern protruded from the face of the column. These projecting roses were present to all columns excluding a single isolated location and no typical defect was recorded with each however, a number of the roses showed a slight loss of definition where surface corrosion and rust staining had occurred. Approximately half of the column capitals exhibited rust staining and surface level corrosion to base and face of the capital sections. Where rust staining was observed to the face of the

capital the upper surface of the column was also typically affected and the source of the defect appeared to be related to water ingress from the roof / gutter details.

- 5.3 Each internal column had been previously shrouded in a timber framework supporting a perimeter netting, positioned approximately 200mm from the face of the column on each side. The addition of the timber and netting follows recommendations previously made by Thomasons due to the risk to the building users from falling debris from the internal columns. The upper decorative detail to column B6 was previously reported as having fallen from the face of the column due to corrosion of the restraining fixing.
- 5.4 An ornate corbel detail was present to the underside of the lattice trusses at the support location to the adjacent columns. The corbel detail was believed to be formed of cast iron and was fixed to the head of the column but with no connection to the lattice truss. Bolt holes were present in the upper plate of the corbel to either side, assumed to be for fixings to the upper truss, however no bolts were present. It was unclear if any bolts had been installed at the time of construction. Separation of the lower flange of the lattice trusses and the corbel to the supporting columns was observed to the majority of interfaces. The degree of separation varied between columns but was typically between 0-20mm for the corbel towards the centre of the property and between 5-40mm for the corbel towards the perimeter of the structure. The larger observed separation between the metal surfaces had been historically packed although this typically occurred to only the greatest of gaps between the metal surfaces, measuring between 30-45mm. The displacement of the head of each column was evident in the rotation of the corbel and spaces observed between the corbel and truss.
- 5.5 The wrought iron lattice trusses, spanning between cast iron columns, were typically in a reasonable condition outside of locations where ongoing water ingress had caused localised corrosion and delamination of the metal sections. Where water ingress around the head of a column was noted, particularly to those columns with plastic sheeting acting as a local gutter hopper around the head of the column, surface corrosion of the lower portion of the cross bracing, along the centre of the lattice, was visible. Although the degree to which corrosion had occurred could not be fully established, the condition of the metal between the bottom plate and the two lower angle sections was suspected to be in a relatively poor condition as water may become trapped and result in greater corrosion to that observed. The lattice trusses noted to be in the worst condition were typically those immediately surrounding the central area and diagonally spanning trusses.

- 5.6 The majority of internal columns displayed minor rust staining to the upper portion of the column, around the capital and around the upper decorative motif of the columns. It is understood that the columns function as the rainwater pipes for the structure and had, since the initial construction, been internally lined with rainwater pipes. The water ingress to the structure had resulted in corrosion and delamination of the metal work around the joints and base of the capital. Two of the internal columns had a plastic sheeting installed around the head of the column which was understood to form an internal rain water hopper to collect water which was leaking through the building fabric. The hopper head was drained via a small pipe which discharged approximately 0.5m above ground level into a lined timber box out arrangement at the base of the column.
- 5.7 The roof trusses of the side aisles comprised back to back angle top chords with internal circular hollow section bracing in a raised tie scissor truss arrangement. An arched truss had been bolted to the top chord of the primary truss to form a raised area around the apex of each aisle. Typically, the aisle trusses were free from defects excluding isolated local issues which are included in the accompanying repair schedule attached in Appendix A. The recorded defects include two trusses identified to have local fractures in the metal work of the brackets which connected the upper chord to the internal bracing, and the connections to several of the trusses had been redrilled to realign the fixings of the arched apex portion of the truss. It was unclear if this was undertaken post construction although the alteration is not suspected to compromise the integrity of the primary truss or the arched apex truss.
- 5.8 The arched trusses that span over the central aisle of the structure comprised an arched lattice of back to back angle top and bottom chords, lattice plate cross bracing web and an outer lattice plate riveted to the angle chords. An additional raised apex of the structure was formed by an additional arched truss rivetted to the top chord of the truss. The arched trusses were typically in a reasonable condition with few surface defects recorded. Separation of the vertical member at the apex of the structure was observed to each truss. The degree to which separation occurred varied but was typically estimated at between 2-5mm. The separation of the apex is believed to be a longstanding issue related to the deflection of the overall structural frame. The central vertical member to the apex frame was typically held in position with a single bolt on one side of the truss. A second bolt hole was observed on the reverse side of the truss however the second bolt was typically missing, and the prop held in place with a single fixing. The lack of second fixing and the general deflection of the overall frame appeared to have resulted in the

displacement/rotation of the upper prop from the assumed position at the time of construction.

- 5.9 The trusses spanning between grid lines 5 and 6 along the centre of the structure between the front and rear elevations were typically in a reasonable condition with no defects recorded to the primary members that comprise the latticework arched truss, however a number of rivets were recorded as missing towards the apex of each frame. The missing rivets tended to occur to the same area of the truss to the top and bottom flange. It is unclear if the rivets were originally installed at the time of construction or if these had subsequently failed and been removed.
- 5.10 Approximately 50% of the roof construction to the central and side aisles towards the lefthand side of the structure was partially obscured by a netting that had been installed at eaves level, making accurate recording of defects difficult. The purpose of the netting was unclear as it does not extend to the full area of the internal space.
- 5.11 The timber rafters of the roof construction typically appeared to be in a reasonable condition with no visible defects, but a close up inspection could not be made as part of this survey. Long term water ingress should be avoided where possible due to the possibility of rot establishing within the timber.
- 5.12 The timber window frames to the perimeter of the property were typically in a reasonable condition with no consistent defects recorded to the timber although a thorough inspection of all the internal timber works was not conducted during the inspection.
- 5.13 The majority of the defects noted during our inspection were of a longstanding nature. These have been indicated on the schedule for future attention.

5.14



General view internally

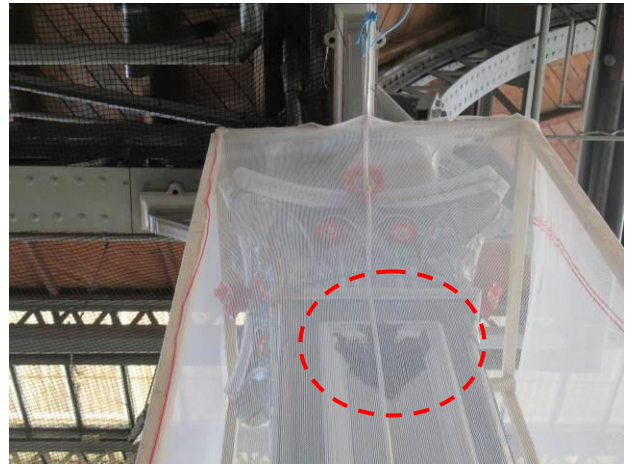


Typical view along length of structure

5.15

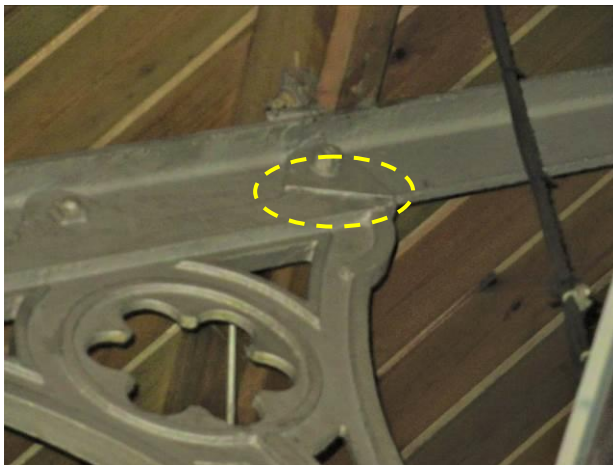


Local box out and tanking to the base of columns where water ingress has been historically observed

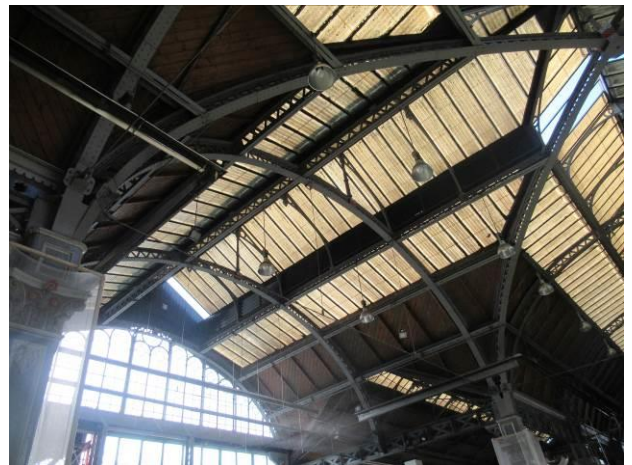


Missing upper crest motif to internal column

5.16



Metal fracture to lower bracket of aisle roof truss

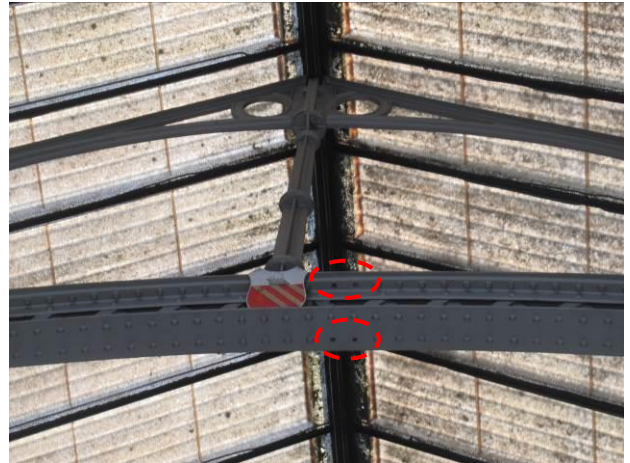


Central ties not installed across diagonal trusses

5.17



View on apex detail for centre aisle trusses, showing vertical member



Missing rivets to the arched roof trusses.

6.0 DISCUSSIONS AND CONCLUSIONS

- 6.1 The majority of the defects noted during our inspection were of a longstanding nature and do not require immediate action. They do not represent defects which will have a detrimental effect on the performance of the structure of the building.
- 6.2 It was apparent from our inspection that the building had suffered distortion since the original construction. This has resulted in the out of plumb nature of the columns and the inconsistent bearing details of the longitudinal lattice trusses. The addition of the tie members retrospectively installed to the base of the trusses should limit further spread of the roof trusses.
- 6.3 As part of our review of the structure of the building we have taken note of a paper presented in 2007 to the Manchester Association of Engineers by Hubert Dickson. The paper discusses the conversion of the City Hall (an open sided market hall) into the Air and Space Museum. A copy of the paper is included in Appendix B of this report.
- 6.4 Hubert Dickson discussed the history of the building and the works undertaken to convert the building as it currently stands. As part of his work Mr. Dickson undertook calculations to prove the load carrying capacity of the arched lattice trusses; unfortunately, those calculations were not included as part of his paper. The reported outcome of the calculations was that the existing structure did not have capacity to support a natural slate roof, as would have been the original roof covering, when considered under the British Standard loading requirements when the conversion work was undertaken circa 1980. As a result, agreement was reached with English

Heritage to reduce the loading by replacing the natural slate with a mineral fibre slate.

- 6.5 In addition to reducing the roof loading, agreement was reached to allow the installation of tie bars at the springing point of the arched trusses at the crossing point of the main aisles; however diagonal ties were not installed as the Heritage England Engineer contesting the installation of the ties, due to the listed nature of the structure argued that those installed to the aisles effectively formed a square of ties around the central area and as such the diagonally spanning ties were not required. At the time of our inspection, we noted that at least one of the tie bars could be seen to be slack; this is indicative of some movement of the structure since the installation of these ties.
- 6.6 We do not consider that the displacement of the columns and subsequent roof spread is of immediate concern relating to the stability of the building however this is an area that we consider should receive further investigation. In the first instance we propose that a permanent monitoring system should be installed to allow repeat measurements to be undertaken so that a proper comparison may be made. This would require the installation of discrete pairs of screws or pins into the columns, one at the top and the other near the base, to allow repeatable readings to be taken.
- 6.7 Dependent on the findings of the monitoring it may be that the matter of installing diagonal tie rods may need to be considered again should evidence of continued movement of the structural frame be recorded.
- 6.8 The water ingress into the structure around the head of individual columns has resulted in the local deterioration of the ironwork to the adjacent trusses, especially at the connection points. The delamination and corrosion of the longitudinal lattice trusses occurred most prevalently to the areas where water could become trapped, particularly to the centre of the truss between the two angle sections of the lower chord. If water ingress and corrosion is allowed to continue the reduction in strength of the truss could result in warping of the metalwork due to expansion of the plates or local failure of the member adjacent to the connections. The worst affected lattice trusses appear to occur immediately around the central diagonally spanning trusses however further defects may occur in the areas not accessible during the inspection.
- 6.9 The cause of the local fractures observed to the aisle truss connections to the north side of the structure could not be established, however the apparent long standing nature of the problem

and lack of further defect with the affected trusses suggests that the structure has reached an equilibrium and the remaining connections were suitable to support the roof structure.

- 6.10 The observed separation of the vertical member at the apex of the structure had occurred as a result of the general distortion of the structural frame. The separation did not appear to have imparted excessive stresses on the surrounding members which were typically free from visible defects. The separation of the apex was not considered to be of structural concern. The missing rivets observed to the majority of the apex prop connections may have occurred due to the distortion of the frame although it was unclear if these connections were present at the time of construction. Due to the perceived longstanding nature of the defect and should the building be free from further roof spread, the lack of second fixing at the head of the prop is not considered to be of structural concern although a second fixing could be introduced to improve the connection should the bolt holes of the two plates align.
- 6.11 The corrosion, loss of definition and loss of section to the decoration on the façade of the structure is considered decorative only however due to the listed nature of the structure consideration should be given to the protection and restoration of these elements. The wider corrosion to the external surface of the columns should be removed and a suitable paint specification applied to prevent further corrosion of the metalwork. The missing decorative crest at the head of the rear lefthand column should be replaced or sealed to prevent water ingress into the centre of the column.
- 6.12 The corrosion, delamination and expansion of the external wrought iron trusses observed at the support locations had occurred due to bimetallic corrosion or trapped water between the metal plates. The reaction between the mild steel haunch sections, which were historically introduced, and the wrought iron has resulted in the local distortion of the bottom chord of the truss and the upper plate of the haunch. Further corrosion should be prevented where possible with the removal of the existing loose corroded metal and the application of a suitable protective paint to seal the metalwork from the atmospheric moisture that accelerates the process. The future degradation of the trusses could result in the local buckling and possible failure of the trusses at the connection points. Note that the extent of bi-metallic corrosion does not appear as progressive as that observed to the Upper Campfield site.

- 6.13 When considering the installation of any new ceilings or thermal improvements to the roof we suggest that the extent of insulation that is proposed should be considered carefully as one consequence of improving the heat retention is that it will potentially allow a greater buildup of snow on the roof which will increase the loading to which it is subject in the future.

7.0 RECOMMENDATIONS

- 7.1 We recommend that the following remedial works are undertaken to extend the longevity of the structural integrity of the property. The recommendations below are to be read in conjunction with the repair schedule included in Appendix A of this report. The works which are required are listed in the schedule each with an indication of the timescale in which it should be done.

1. Undertake the local clean, removal of flaking paintwork and repainting of corroded and pitted metalwork to the external façade of the structure. Remove all loose, delaminated metal work but consider a suitable paint protection, such as Carbomastic 15LT by Carboline, to seal the existing metalwork without the requirement to clean back to reliable metal.
2. Remove all bird droppings from the face of the external metalwork and consider the installation of protective measures, within the acceptable limits of the building listing, to prevent birds roosting below the eaves of the property or incorporate cleaning into the routine maintenance schedule of the property.
3. Undertake further investigations to the head of the columns shrouded in plastic guttering and any areas where the roof is leaking. Undertake remedial works as required to ensure the property is otherwise sealed from water ingress. Waterproofing and sealing works to architect specifications.
4. Once roof investigations and sealing works have been undertaken, consider the removal of the existing sheeting and tanking to the head and base of the internal columns.
5. Ensure that all decorative motifs are adequately fixed to the existing columns and not currently loose. To allow the removal of the existing netting and timber framework to each internal column it is recommended that remedial fixings are introduced to all motifs on columns where water ingress is apparent.

6. Undertake local clean and repainting of corroded ironwork within the structure including, but not limited to, truss ends, column heads, column capitals and truss members.

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Lower Campfield Market Hall, Liverpool Road, Manchester

AW/11112

APPENDIX A

STRUCTURAL DEFECT AND REPAIR SCHEDULE

Proposed Spreadsheet for Lower Campfield, Liverpool Road, Manchester

For GL's see "11112 Thomasons GL for defect schedule"

External Works Reference	GL/Location	Description	Component	Photograph Reference	Condition	Asset Condition Description	Remedial Work Recommendation	Priority	Further Investigation Y/N	Investigation Description	Works Cost	Comments
External Works												
01	1A	Square column	Column base & capital	IMG_5395-5396 IMG_5465	A/C/J	Rust staining and corrosion to base of capital.	Clean and repaint	Soon	N	N/A		
02	2A	Square column	Column base & capital	IMG_5397-5399	A/C/J	Rust staining and corrosion to base of capital.	Clean and repaint	Soon	N	N/A		
03	3A	Circular column	Column base & capital	IMG_5400	A/C/F/G/J	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
04	4A	Circular column	Column base & capital	IMG_5402-5403	A/C/F/G/J	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
05	5A	Square column	Column base & capital	IMG_5404-5406	A/C/F/G/J	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
06	6A	Square column	Column base & capital	IMG_5408-5409	A/C/F/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing. Algae growth to base and head of column.	Clean and repaint	Soon	N	N/A		
07	7A	Circular column	Column base & capital	IMG_5410-5411	A/B/C/F/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of section of the capital joints.	Clean and repaint. Replace and/or seal the missing capital section	Soon	N	N/A		
08	8A	Circular column	Column base & capital	IMG_5412-5413	A/C/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Algae growth and water staining to base of column.	Clean and repaint	Soon	N	N/A		
09	9A	Circular column	Column base & capital	IMG_5414-5415	A/C/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Algae growth and water staining to base of column.	Clean and repaint	Soon	N	N/A		
10	10A	Square column	Column base & capital	IMG_5416-5417	A/C/F/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing. Algae growth and water staining to base of column.	Clean and repaint	Soon	N	N/A		
11	11A	Square column	Column base & capital	IMG_5418-5421	A/B/C/F/G/J/M	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing. Loss of crest motif and water staining around the opening. Algae growth to the capital and column base	Clean and repaint. Replace and/or seal the existing crest motif.	Soon	Y	Investigate the condition of the inside face of the column in and around the missing motif.		
12	11B	Square column	Column capital	IMG_5422-5424	A/C/F/G/J	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
13	11C	Square column	Column capital	IMG_5431-5425	A/C/F/G/J	Rust staining and pitting to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
14	1D	Square column	Column base & capital	IMG_5456-5458	A/F/G/J	Rust staining to column capital, corrosion and pitting to upper column	Clean and repaint	Soon	N	N/A		
15	2D	Square column	Column base & capital	IMG_5450 IMG_5452-5455	A/F/G/H/J	Rust staining to column capital, corrosion and pitting to upper column. Local fracture to base of column to lefthand side	Clean and repaint	Soon	N	N/A		
16	3D	Circular column	Column base & capital	IMG_5449 IMG_5451	A/C/D/E/F/G/J	Rust staining to column capital. Local corrosion and delamination of capital at joints and upper section. Loss of definition to capital detailing. Upper rose motif missing.	Clean and repaint	Soon	N	N/A		
17	4D	Circular column	Column base & capital	IMG_5448	A/C/F/G/J	Rust staining to column capital. Local corrosion and delamination of capital at joints and upper section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
18	5D	Square column	Column capital	IMG_5446-5447	A/F/G/J	Rust staining to the column capital. Connection to modern stiffener not visible.	Clean and repaint	Soon	N	N/A		
19	6D	Square column	Column capital	IMG_5441 IMG_5447	A/F/G/J	Rust staining to the column capital. Connection to modern stiffener not visible.	Clean and repaint	Soon	N	N/A		
20	7D	Circular column	Column capital	IMG_5440	A/G/J/K	Rust staining to column capital. Local corrosion an pitting of capital upper section.	Clean and repaint	Soon	N	N/A		
21	8D	Circular column	Column capital	IMG_5437-5438	A/G/J/K	Rust staining to column capital. Local corrosion an pitting of capital upper section.	Clean and repaint	Soon	N	N/A		
22	9D	Square column	Column capital	IMG_5435-5436	A/B/F/J/K	Rust staining to column capital. Local corrosion an pitting of capital upper section. Loss of section to base of capital	Clean and repaint	Soon	N	N/A		
23	11D	Square column	Column capital	IMG_5431-5433	A/C/F/G	Rust staining to column capital. Local corrosion and delamination of capital at joints and lower section. Loss of definition to capital detailing.	Clean and repaint	Soon	N	N/A		
24	1B	Square column	Column capital	IMG_5461	A/C/J	Rust staining and corrosion to base of capital.	Clean and repaint	Soon	N	N/A		
25	1C	Square column	Column capital	IMG_5464	A/C/J	Rust staining and corrosion to base of capital.	Clean and repaint	Soon	N	N/A		
Internal Columns												
26	2B	Circular column	Column capital	IMG_5245-5247 IMG_5254-5256	E	Separation of corbel to adjacent flat truss, historically packed.	No action required	N/A	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
27	3B	Circular column	Column capital	IMG_5243-5244	E/J	Separation of corbel to adjacent flat truss, historically packed. Minor water staining to below corbel	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
28	4B	Circular column	Column capital	IMG_5242	E/J	Separation of corbel to adjacent flat truss. Water staining to face of column full height originating from joint in corbel	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
29	5B	Square column	Column capital	IMG_5236	E/J	Separation of corbel to adjacent flat truss. Water staining from base of upper crest motif.	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
30	6B	Square column	Column capital	IMG_5227-5228 IMG_5232	D/E/J	Separation of corbel to adjacent flat truss. Missing upper crest motif to east elevation, water staining around base of missing crest.	Clean and repaint. Replace and/or seal the missing asset.	Soon	N	N/A		
			Column base		J	Heavy rust staining to the base of the column.	Clean and repaint	N/A	N	N/A		
31	7B	Circular column	Column capital	IMG_5224	E/J	Separation of corbel to adjacent flat truss. Water staining to face of column to upper portion originating from joints in capital. Minor scratches to paintwork to the lower portion of the column	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
32	8B	Circular column	Column capital	IMG_5222	E/J	Separation of corbel to adjacent flat truss. Water staining to face of column full height originating from joint in corbel	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		

Defect key	
Reference	Defect description
A	Surface corrosion
B	Loss of section
C	Delamination
D	Missing asset
E	Separation of metalwork
F	Loss of definition to asset
G	Pitting to metal surface
H	Local metal fracture
J	Water staining
K	Loss of paintwork
L	Sagging member
M	Algae growth

Internal Works Reference	GL/Location	Description	Component	Photograph Reference	Condition	Asset Condition Description	Remedial Work Recommendation	Priority	Further Investigation Y/N	Investigation Description	Works Cost	Comments
33	9aB	Circular column	Column capital	IMG_5220-5221	E/J	Separation of corbel to adjacent flat truss. Water staining to face of column full height originating from joint in corbel. Capital shrouded in plastic sheeting as gutter. Pipe from gutter terminates at base of column	Clean and repaint. Replace existing gutter outlet and make water tight	Soon	N	N/A		
			Column base		J	Extensive water staining at base of the column, particularly around the outlet of gutter.	Clean and repaint	Soon	N	N/A		
34	2C	Circular column	Column capital	IMG_5269-5274	E/J	Separation of corbel to adjacent flat truss. Water staining to face of column full height originating from joint in corbel. Capital shrouded in plastic sheeting as gutter. Pipe from gutter terminates at base of column	Clean and repaint. Replace existing gutter outlet and make water tight	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
35	3C	Circular column	Column capital	IMG_5275	E/J	Separation of corbel to adjacent flat truss. Water staining to capital of column originating from joint in corbel	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
36	4C	Circular column	Column capital	IMG_5279	E/J	Separation of corbel to adjacent flat truss. Minor paint scratches to column mid height	Clean and repaint damaged paintwork	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
37	5C	Square column	Column capital	IMG_5279-5281	J	Rust staining to capital and from base of upper crest motif	Clean and repaint	Soon	N	N/A		
			Column base		J	Heavy rust staining to the base of the column	Clean and repaint	Soon	N	N/A		
38	6C	Square column	Column capital		B/J	Rust staining to base of capital and around the base of the upper crest motif to west elevation. Local damage to upper section of capital on south elevation	Clean and repaint	Soon	N	N/A		
			Column base		J	Heavy rust staining to the base of the column	Clean and repaint	Soon	N	N/A		
39	7C	Circular column	Column capital		E/J	Separation of corbel to adjacent flat truss. Water staining to capital of column originating from joint in corbel	Clean and repaint	Soon	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
40	8C	Circular column	Column capital		E	Separation of corbel to adjacent flat truss, historically packed.	No action required	N/A	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
41	9aC	Circular column	Column capital	IMG_5193/5196	E	Separation of corbel to adjacent flat truss, historically packed.	No action required	N/A	N	N/A		
			Column base		N/A	No defects recorded	No action required	N/A	N	N/A		
Perimeter Columns												
42	1A	Square column	Column capital		Not visible	Hidden behind internal plasterboard	TBC	N/A	Y	Investigate condition of internal column		
43	2A	Square column	Column capital		N/A	No defects recorded	No action required	N/A	N	N/A		
44	3A	Circular column	Column capital		Not visible	Hidden behind internal plasterboard	TBC	N/A	Y	Investigate condition of internal column		
45	4A	Circular column	Column capital		Not visible	Hidden behind internal plasterboard	TBC	N/A	Y	Investigate condition of internal column		
46	5A	Square column	Column capital	IMG_5237-5238	A/C/G/J	Major corrosion and delamination to column capital. Water/rust staining and pitting to capital. Source of water appears to come from a fixing point.	Clean and repaint	Soon	N	N/A		
47	6A	Square column	Column capital	IMG_5229-5230	A/J	Major water/rust staining to base of capital and upper column	Clean and repaint	Soon	N	N/A		
48	7A	Circular column	Column capital		A/C/J	Minor corrosion and delamination to the capital base.	Clean and repaint	Soon	N	N/A		
49	8A	Circular column	Column capital	IMG_5226	N/A	No defects recorded	No action required	N/A	N	N/A		
50	9A	Circular column	Column capital	IMG_5223	N/A	No defects recorded	No action required	N/A	N	N/A		
51	10A	Square column	Column capital		N/A	No defects recorded	No action required	N/A	N	N/A		
52	11A	Square column	Column capital	IMG_5216	E	Minor separation to capital	No action required	N/A	N	N/A		
53	1B	Square column	Column capital		J	Minor rust staining to capital joints	Clean and repaint	Soon	N	N/A		
54	1C	Square column	Column capital	IMG_5265-5268	A/G/J	Corrosion, pitting and rust staining to the capital base. No defects to upper column	Clean and repaint	Soon	N	N/A		
55	11B	Square column	Column capital	IMG_5211-5212	A/C	Minor corrosion and delamination to the capital base.	Clean and repaint	Soon	N	N/A		
56	11C	Square column	Column capital	IMG_5206	A/J	Major water/rust staining to base of capital and upper column	Clean and repaint	Soon	N	N/A		
57	1D	Square column	Column capital		Not visible	Hidden behind internal plasterboard	TBC	N/A	Y	Investigate condition of internal column		
58	2D	Square column	Column capital		N/A	No defects recorded	No action required	N/A	N	N/A		
59	3D	Circular column	Column capital	IMG_5278	A/C/J	Minor corrosion and delamination to the capital base.	Clean and repaint	Soon	N	N/A		
60	4D	Circular column	Column capital	IMG_5280	A/C/G/J	Corrosion, pitting and rust staining to the capital base. No defects to upper column	Clean and repaint	Soon	N	N/A		
61	5D	Square column	Column capital		Not visible	Not accessible due to ongoing works	TBC	N/A	Y	Investigate condition of internal column		
62	6D	Square column	Column capital		J	Minor rust staining to capital joints and upper capital section	Clean and repaint	Soon	N	N/A		
63	7D	Circular column	Column capital	IMG_5188-5190	N/A	No defects recorded	No action required	N/A	N	N/A		
64	8D	Circular column	Column capital		N/A	No defects recorded	No action required	N/A	N	N/A		
65	9aD	Square column	Column capital		Not visible	Hidden behind internal plasterboard	TBC	N/A	Y	Investigate condition of internal column		
66	11D	Square column	Column capital	IMG_5201	A/C/J	Minor corrosion and delamination to visible portion of capital.	Clean and repaint	Soon	N	N/A		
Flat Trusses												
67	1B-2B	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
68	2B-3B	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
69	3B-4B	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
70	4B-5B	Lattice truss	Truss connections and midspan		A/C	Corrosion to each cross brace at base, possible corrosion of bottom chord between lower members.	Clean and repaint	Immediate	N	N/A		
71	6B-7B	Lattice truss	Truss connections and midspan		A/C	Corrosion to each cross brace at base, possible corrosion of bottom chord between lower members. Corrosion typically to column 6B	Clean and repaint	Immediate	N	N/A		
72	7B-8B	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
73	8B-9aB	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
74	9aB-11B	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
75	1C-2C	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
76	2C-3C	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		

Defect key	
Reference	Defect description
A	Surface corrosion
B	Loss of section
C	Delamination
D	Missing asset
E	Separation of metalwork
F	Loss of definition to asset
G	Pitting to metal surface
H	Local metal fracture
J	Water staining
K	Loss of paintwork
L	Sagging member
M	Algae growth

Internal Works Reference	GL/Location	Description	Component	Photograph Reference	Condition	Asset Condition Description	Remedial Work Recommendation	Priority	Further Investigation Y/N	Investigation Description	Works Cost	Comments
77	3C-4C	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
78	4C-5C	Lattice truss	Truss connections and midspan		A/C	Corrosion to each cross brace at base, possible corrosion of bottom chord between lower members. Corrosion typically to column 6B	Clean and repaint.	Immediate	Y	Identify source of water ingress and remediate		
79	6C-7C	Lattice truss	Truss connections and midspan		A/C	Corrosion to each cross brace at base, possible corrosion of bottom chord between lower members. Corrosion typically to column 6C Water continually dripping from roof adjacent to column 6C	Clean and repaint	Immediate	N	N/A		
80	7C-8C	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
81	8C-9aC	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
82	9aC-11	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
83	2A-2B	Lattice truss	Truss connections and midspan		N/A	Holes within top chord of member. Does not compromise member structurally.	No action required	N/A	N	N/A		
84	2C-2D	Lattice truss	Truss connections and midspan		N/A	Holes within top chord of member. Does not compromise member structurally.	No action required	N/A	N	N/A		
85	5A-5B	Lattice truss	Truss connections and midspan	IMG_5234-5235	E	Minor separation to adjacent column at each end	No action required	N/A	N	N/A		
86	5C-5D	Lattice truss	Truss connections and midspan		A/N	Missing bolts at end connection point. Lattice appears otherwise connected. Corrosion delamination to bottom chord of lattice at corbel	Clean and repaint.	Immediate	N	N/A		
87	6A-6B	Lattice truss	Truss connections and midspan	IMG_5231-5232	N	Missing bolts at end connection point. Lattice appears otherwise connected.	No action required	N/A	N	N/A		
88	6C-6D	Lattice truss	Truss connections and midspan		N	Missing bolts at end connection point. Lattice appears otherwise connected.	No action required	N/A	N	N/A		
89	9aA-9aB	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
90	9aC-9aD	Lattice truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
Arched Trusses												
91	2B-2C	Arched truss	Truss connections and midspan		E/K/N	1No bolt missing and separation of to apex connection. Small area of paint damage to righthand end of western elevation	Clean and repaint. Replace missing fixing.	Soon	N	N/A		
92	3B-3C	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection. 1No missing rivet at upper portion of truss.	Replace missing fixing to apex	Soon	N	N/A		
93	4B-4C	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection.	Replace missing fixing to apex	Soon	N	N/A		
94	5B-5C	Arched truss	Truss connections and midspan		E/J/N	1No bolt missing and separation of to apex connection. Water ingress from upper lefthand connection to west elevation	Replace missing fixing to apex. Seal water ingress	Soon	N	N/A		
95	6B-6C	Arched truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
96	7B-7C	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection.	Replace missing fixing to apex	Soon	N	N/A		
97	8B-8C	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection.	Replace missing fixing to apex	Soon	N	N/A		
98	9aB-9aC	Arched truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
99	5A-6A	Arched truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
100	5Aa-6Aa	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection. 5No missing rivet at upper portion of truss to (3No) top and (2No) bottom chord.	Replace missing fixing to apex	Soon	N	N/A		
101	5B-6B	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection. 7No missing rivet at upper portion of truss to (4No) top and (3No) bottom chord.	Replace missing fixing to apex	Soon	N	N/A		
102	5C-6C	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection. 6No missing rivet at upper portion of truss to (4No) top and (2No) bottom chord.	Replace missing fixing to apex	Soon	N	N/A		
103	5Ca-6Ca	Arched truss	Truss connections and midspan		E/N	1No bolt missing and separation of to apex connection. 4No missing rivet at upper portion of truss to (3No) top and (1No) bottom chord.	Replace missing fixing to apex	Soon	N	N/A		
104	5D-6D	Arched truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
105	5B-6C	Arched truss	Truss connections and midspan		D	Restraint tie to springing points missing. Historical compromise/decision made by English Heritage Engineer	No action required	N/A	N	N/A		
106	6B-5C	Arched truss	Truss connections and midspan		D	Restraint tie to springing points missing. Historical compromise/decision made by English Heritage Engineer	No action required	N/A	N	N/A		
Roof Trusses												
107	2A-2B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
108	2aA-2aB	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
109	3A-3B	Roof truss	Truss connections and midspan		N	Redrilled fixings to upper truss, 1No fixings missing both elevations	Replace missing fixing to apex	Soon	N	N/A		
110	3aA-3aB	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
111	4A-4B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
112	4aA-4aB	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
113	5A-5B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
114	6A-6B	Roof truss	Truss connections and midspan		H	Local fracture to lower bracket to east elevation	No action required	N/A	N	N/A		
115	6aA-6aB	Roof truss	Truss connections and midspan		N/A	Redrilled fixings to upper truss, no missing fixings.	No action required	N/A	N	N/A		
116	7A-7B	Roof truss	Truss connections and midspan		H	Local fracture to lower bracket to east elevation	No action required	N/A	N	N/A		
117	7aA-7aB	Roof truss	Truss connections and midspan		K	Local paintwork damage to upper chord to east elevation	Clean and repaint	Soon	N	N/A		
118	8A-8B	Roof truss	Truss connections and midspan		J	Rust staining to lower connection to the lefthand side of east elevation	Clean and repaint	Soon	N	N/A		
119	8aA-8aB	Roof truss	Truss connections and midspan		J	Rust staining to lower connection to the lefthand side of east elevation	Clean and repaint	Soon	N	N/A		

Defect key	
Reference	Defect description
A	Surface corrosion
B	Loss of section
C	Delamination
D	Missing asset
E	Separation of metalwork
F	Loss of definition to asset
G	Pitting to metal surface
H	Local metal fracture
J	Water staining
K	Loss of paintwork
L	Sagging member
M	Algae growth
N	Missing fixing

Internal Works Reference	GL/Location	Description	Component	Photograph Reference	Condition	Asset Condition Description	Remedial Work Recommendation	Priority	Further Investigation Y/N	Investigation Description	Works Cost	Comments
120	9A-9B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
121	9aA-9aB	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
122	2C-2D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
123	2aC-2aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
124	3C-3D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
125	3aC-3aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
126	4C-4D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
127	4aC-4aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
128	5C-5D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
129	6C-6D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
130	6aC-6aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
131	7C-7D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
132	7aC-7aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
133	8C-8D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
134	8aC-8aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
135	9C-9D	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
136	9aC-9aD	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
137	1B-2B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
138	9aB-11B	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
139	1C-2C	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		
140	9aC-11C	Roof truss	Truss connections and midspan		N/A	No defects recorded	No action required	N/A	N	N/A		

Defect key	
Reference	Defect description
A	Surface corrosion
B	Loss of section
C	Delamination
D	Missing asset
E	Separation of metalwork
F	Loss of definition to asset
G	Pitting to metal surface
H	Local metal fracture
J	Water staining
K	Loss of paintwork
L	Sagging member
M	Algae growth
N	Missing fixing



THOMASONS

Lower Campfield Market Hall, Liverpool Road, Manchester

AW/11112

APPENDIX B

MANCHESTER ASSOCIATION OF ENGINEERS

AN ILLUSTRATED TALK ON THE CONVERSION OF THE VICTORIAN CITY HALL INTO THE AIR &
SPACE MUSEUM

By Hubert Dickson

MANCHESTER ASSOCIATION OF ENGINEERS

An
illustrated talk
on the

CONVERSION

of the

VICTORIAN

CITY HALL

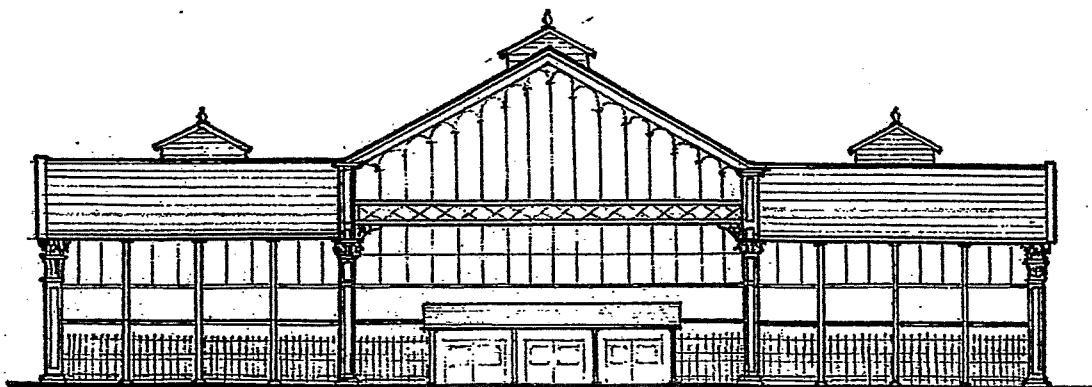
into the

AIR & SPACE

MUSEUM

by

Hubert Dickson CEng. F1StructE. MMAE.



MANCHESTER ASSOCIATION OF ENGINEERS

An
illustrated talk on the

CONVERSION
of
THE VICTORIAN CITY HALL
into the
AIR & SPACE MUSEUM

by
Hubert Dickson CEng. FIStructE. MMAE.

Introduction

Numerous buildings, throughout their life span, are used for various purposes other than that for which they were originally designed.

This is very much the case in respect of the 'listed' building which is now known as the Air and Space Gallery at the Museum of Science and Industry in Manchester.

The paper/talk charts the changes in the structure and usage which have occurred, over the past 130 years, to the building now housing the Air and Space Gallery. The fact that this Victorian building has remained standing, and continues to provide a worthwhile service to a wide section of the general public, is a testimony and tribute to the skills and abilities of its original designers, and those who have maintained, restored and, where necessary, enhanced the building throughout the 130 years of its existence.

To understand the complexities of the building and appreciate the classic design of the structure, together with its architectural embellishments, we need to go back to the 19th century; to the point of its inception.

Background History

In 1876, the Manchester architectural practice of Mangnall and Littlewood was commissioned to design two open sided Market Halls in the Campfield area, on the south-west side of the city.

The site chosen for the Halls was a parcel of land which, in the 13th century, had been the city's "fayre" ground, where regular trading events took place allowing people from the outlying areas to congregat^e and sell their produce, wares and homemade articles to the city dwellers and local merchants.

In 1820, however, the "fayre" ground was bisected by the erection of St Matthews Church, in the centre of the plot. (The church was designed by Charles Barry, the architect responsible for the design of the Houses of Parliament) The church was opened in 1825, and demolished in 1952. The land on either side of the church was still used for trading and dealing, and, in the 1870's, it was decided that covered areas should be provided for those still using the facilities as traders or buyers.

The two Market Halls, therefore, were designed as separate buildings, but similar in their style, construction and appearance. (See Fig. No.1)

The buildings were to be known as the Upper and Lower Campfield Market Halls; being positioned on Liverpool Road, either side of the church. The Market Hall nearest to Deansgate was denoted as Upper Market Hall, while the one set further along Liverpool Road, towards the west, was known as the Lower Market Hall.

These two Market Halls opened for trading between 1873 and 1880.

Both buildings are still in existence to this day, and it is the Lower Campfield Market Hall, in particular, which is the subject of this paper/talk.

The Buildings

Historically, in England, most large towns had "Market Halls" rather than market places. These "Halls" were usually buildings of distinction; being of architectural design in decorative stonework, and standing in a prominent position near to the town centre.

In Manchester, in 1876, the task facing the architect was somewhat different; and there can be no doubt that when the practice of Mangnall and Littlewood deliberated over the design for the two new Market Halls, it must have been influenced by the fact that the gothic structure of Barry's St Matthews church would continue to dominate the site.

Although the new buildings were to be open sided market halls, the architect endeavoured to produce an atmosphere of grandeur within the designs, which would equal that of the church.

Instinctively, the architect responded, and produced two "cathedral like" structures, with fifty foot wide cross aisles and curved arches forming the roof.

These arches were constructed to embrace the latest technology of wrought iron latticeworks; providing an ambience of spaciousness and lightness, while rising up from the caps of slender cast iron columns to a height of 40 feet (12m) above the market floor. (See Fig.No. 2)

At the centre of the buildings, where the two main aisles intersect, forming a cross, the latticed arches span 75 feet (23m) diagonally across this intersection, thus achieving an internal domelike appearance.

The market halls are also provided with two side aisles which run either side of, and parallel with, the main aisle; extending the whole length of the buildings. The roofs to the side aisles are supported on wrought iron roof trusses of 35 feet (11m) span, embellished with ornate cast iron struts. The trusses are carried on the feet of the main arches and span onto lattice girders and/or cast iron columns along the external sides of the buildings.

Atop each archway and side aisle, there is a raised lantern light which extends continuously along the length of the buildings. These lantern lights are supported by ornate cast iron frameworks, and are roofed over with patent glazing. The general roof covering is formed by slating, resting on battens, which in turn are fixed to 'herring boned' timber boarding. The underside of the boarding forms the ceiling to the halls, and is carried on stout wooden rafters, which span onto longitudinal WI lattice girders.

The architect has further enhanced the interior of the market halls by providing each column cap with 'Corinthian Capitals', stylised with acanthus leaves and floral decorations, all intricately sculptured in cast iron. Each face of the 'Capital' is surmounted by a rose motif, and this feature has also been used to embellish the vertical faces, both internally and externally, of the square shaped cast iron columns around the buildings.

In keeping with the standard tradition of the time, the floors to both market halls were constructed from large 'flag' stone paviers resting on punned earth. At the time the City Hall was created it was decided to make the Hall secure by providing, around the open sides, an ornamental wrought iron railing. Each length of railing to be fixed between the intermediate external columns.

It is interesting to note, that, although many changes have taken place to the building throughout the years, this feature has been retained, in its original format, up to the present day.

The City Hall

At the end of the 19th Century, the Manchester City Council were in control of the two Market Halls, and, in 1900, the City Council decided to close the Lower Campfield Market Hall, and redevelop the building as an exhibition centre. Plans were drawn up for the complete revamping of the building, including the need to fill in the open sides of the original market hall, to provide a fully enclosed and weathertight structure.

Also incorporated, in the new design, was a small upper gallery, measuring 6 feet (1.8m) wide and set 10 feet (3m) above the ground floor level. This gallery was made continuous, to run around the full periphery of the new hall, with access staircase provided at each corner of the building.

The stone flagged floor remained untouched, but was eventually covered over with a screeded topping.

An entranceway into the exhibition hall was created in the east gable facade, and this feature was enhanced with an external, canopy type, covered over porchway. (See Fig.No.3)

The new 'City Hall' was opened in 1902.

Its success as an exhibition centre was immediate; offering displaying facilities, and ample floor space for Manchester's growing textile, engineering and commercial industries to advertise and show off their products.

The City Hall's popularity, in the early years, prompted the City Council to commission the enlargement of the upper gallery. This improvement took place in 1910. The existing gallery was taken down, to make room for the new balcony. This new balcony, like the previous gallery, was built around the entire periphery of the hall, and cantilevered out over a row of new supporting cast iron columns; providing a 15 feet (5m) wide platform; thus adding an extra 10% of displaying area to the 30,000 sq.ft. (275 sq.m) already available.

Throughout the 1920's and 30's the City Council engaged the services of a company, specialising in promotional activities, to organise, manage and run the various exhibitions on their behalf.

This company were successful in maintaining a steady flow of annual trade shows, demonstrations and public orientated events/exhibitions, which were all popular and well attended. It is a known fact that one such exhibition ran until 7pm on Saturday 2nd September 1939; on which date, and at that time, the City Hall closed at the outbreak of World War II.

However, the hall did not remain idle during the years of conflict; its facilities were called into use on a number of occasions. It is recorded that, because of

its size and spaciousness, the hall was used for the manufacture of "barrage balloons".

Remarkably, the City Hall survived the intense Manchester blitz and bombings in the early 1940's. It suffered only superficial damage to glazing and some external finishes.

When hostilities ceased in 1945, and life returned to normal, the City Hall was refurbished, and , by 1947, exhibitions were once again being held within its walls.

The next two decades were probably the most successful in the history of the City Hall as an exhibition centre. The increase in trade around Manchester, and the vitality of the docks at Salford, immediately following the war years, led to more 'trade' orientated exhibitions being presented. At this time the general public were beginning to clamour for more 'contemporary' items around their homes, including furniture, fabrics and wall decorations; to this end, the organisers presented the "Brighter Homes" and "Ideal Homes" exhibitions at the hall. These exhibitions proved so popular with the public, they were repeated on an annual basis.

The City Hall, with its historical background and Victorian style of architecture, prompted the City Council to seek "listing" from English Heritage. Eventually, the building's attributes were obviously recognised by English Heritage, and, on the 17th May 1974, the City Hall was declared a Grade II Listed historical building. Shortly after being 'listed', the boom in demand for exhibition space declined, owing to the economic downturn in the mid-1970's; and, sadly, in 1977 a catastrophe struck the City Hall.

During the course of one exhibition a fire broke out in the restaurant area at the eastern end of the building; and, although dealt with quickly by the Fire Brigade, some substantial damage was caused internally, and areas of the roof were affected. The City Hall was, therefore, CLOSED!

The Political Equation.

Following the fire and closure of the City Hall, there was a period of indecision, during which the Manchester City Council deliberated over what to do with the Victorian building.

Various options for its potential use were considered, but it soon became obvious

that its days as an exhibition centre had run out.

Belle Vue had taken over to fulfil the demand for exhibition facilities in the Manchester area.

The new National Exhibition Centre, in Birmingham, had opened in 1975, and the Greater Manchester Council were already considering using the defunct Central Station railway building as a major exhibition/events venue.

The Manchester City Council politicians were, therefore, faced with an enigmatic problem that had to be solved in some way.

In 1978, the City Council became so concerned about the demise of the City Hall, it actually considered demolishing the building and releasing the land for an alternative development. This was a serious proposal, so much so, that an Application for Consent to Demolish a Listed Building had already been filled-out. The Council, however, decided to put the application on hold, for the time being, until further proposals had been considered; - thus, buying valuable time for the future of the City Hall.

At this time, Councillor Norman Morris was the Leader of the Manchester City Council, and he took a personal interest in the future of the City Hall. He was eager to find a positive new role for this fine Victorian building.

During 1979, a variety of suggestions were considered, including the idea of using the City Hall as a maintenance workshop for the North-west Museum of Science and Industry, or, alternatively, making use of the space for storage of the Museum's larger items of machinery, which were now becoming available as historical artifacts.

One drastic suggestion was to excavate the floor area, inside the City Hall, in search for Roman ruins. Fortunately, this option was never adopted!

In its wisdom, the City Council decided, in 1979, to set up a special sub-committee to consider all possible, or feasible, ideas for the use of the City Hall. At the same time the City Architect was instructed to prepare an estimate of costs for the restoration of the building.

At this point in time, someone within the Town Hall put forward the suggestion that the City Hall might be converted into an "Air and Space Museum", which would portray the involvement of Manchester and the Northwest region in the development of flight and flying machines.

The idea was considered credible by Councillor Morris, and an approach was made to the Director of the RAF Museum, at Hendon, for information on how the project could be set up and moved forward. The Director was delighted to help the City Council, and offered to loan a number of planes and accessories, which he had in storage. These items could be made available for displaying in the

proposed Manchester Air and Space Museum. The proposal was put to the City Council in January 1930, and was unanimously accepted. In the meantime, the City Architect had produced the estimate of cost for the restoration of the building, with additional costings for the likely work needed to turn the City Hall into a viable Air and Space Museum. These estimates of cost were set at £1.2 million with a further on-cost of £0.65 million for fitting out the museum. Subject to satisfactory financial arrangements being made to meet the costs, the City Council gave its approval to the proposed scheme. The 'political equation' had been solved and, henceforth, the City Hall would be known as the Manchester Air and Space Museum.

The Engineer's Problem

To enable the City Architect to produce his estimates of cost, it was essential for a survey to be made of the existing fabric and structure of the City Hall. Naturally, with a building of this character and age, a number of problems were identified. One such problem was that of movements at the head of the columns supporting the large wrought iron arches. The amount of movement varied from as little as $\frac{1}{2}$ inch (15mm) to a significant $1\frac{1}{2}$ ins. (35mm) at some locations. The greatest single outward movement recorded was at the cap of the square cast iron columns, supporting three separate arches, at the point where the two aisles met and converged. A displacement of $2\frac{1}{4}$ ins. (55mm) was noted at the end of the 75 feet (23m) span diagonal cross arches. (See Fig. No. 4)

Obviously, these movements gave cause for concern, basically because it was not clear when these movements had occurred; whether they were of recent origin or had, in fact, accumulated over a period of time. Nonetheless, the arches had spread out laterally, at their springing positions, and there was a possibility that they would continue to move in the future.

If the building was to be restored, for long term usages, then it was imperative that this movement should be investigated and, if possible, arrested.

At this stage, the City Architect's structural engineers carried out an analytical check on the design of the 50 ft. (15.3m) span wrought iron lattice arched member, and were astonished by their findings. Technically, the arched frameworks were found to be just adequate to carry the dead weight of the roof coverings, with little capacity left over to cope with incidental loadings, such as maintenance

loads, heavy snow falls or strong gale force winds.

It is not known who was responsible for the engineering design of the Market Hall structures, but, by today's standards, they would fail to meet the requirements of the current British Standards in respect of incidental loadings.

It is known that the company of E.T. Bellhouse & Co. of Manchester, were responsible for some of the cast iron work and wrought iron fabrications, but there is no documentary evidence to indicate that they were responsible for the overall engineering design and analysis of the structures.

In 1876, the theory of arched structures was well documented, including the fact that a horizontal thrust occurs at the springing level of the arch when acting under loaded conditions. This horizontal thrust was usually resisted by a robust bulwark, or, where the arch was supported on a column capping, a metal tie would be introduced at the springing point, to prevent the tendency for the arch to spread.

In the case of the Market Hall/ City Hall structure, no metal tie bars were included in the initial construction process, and the thrust from the arches, as they flexed, should, therefore, have been resisted by robust frameworks built at each side of the main aisles. This did not happen. (See fig.No.5)

The side aisles are simple frameworks, roofed over by wrought iron trusses, with only slender members forming their frames; these provide little or no 'stiffness' to the overall integrity of the structure.

The structural engineer carried out a further site inspection of the frameworks, and discovered that a number of the sloping rafters of the side trusses were buckled, at, or adjacent to, the apex of the truss. The conclusion was, therefore made, that the unrestrained horizontal force, from the arches, had passed into the adjacent roof trusses, and had been resisted, to some degree, by the rafter member, which had distorted under the additional compressive force.

The structural engineer reported these findings to the City Architect, and pointed out that these defects, having occurred, could not be rectified; but the situation could be resolved by following a set of remedial actions:

- (i) To provide metal tie bars at the springing level of all the curved arches, to hold them in their present position, and prevent any further lateral movement taking place in the future.
- (ii) To introduce a restraining member at the apex of the side aisle trusses, to run across the ridge point and tie each rafter together to prevent further buckling taking place.

- (iii) Some consideration was necessary, during the restoration process, to reducing the overall dead weight of the roof coverings, in order to meet the present day statutory requirements for superimposed loadings.
- (iv) If these recommendations were not accepted it could result in the structures being classed as unacceptable under current Building Regulations.

The City Council took note of these recommendations and agreed to the strengthening works being carried out, as quickly as possible, ahead of the restoration works. Accordingly, a sum of £70,000 was made available, to carry out the tying work to the structure, and also for the clearing of the drainage system. These holding works were commenced in the autumn of 1980.

Conflict of Interests

The holding works were well advanced when the Main Contract for the restoration work was handed to John Laing and Company early in 1981. At the same time, English Heritage were officially notified of the restoration proposals that were to be carried out on their Grade II Listed Building. Understandably, English Heritage wanted to ensure that the listing of the Victorian building was not compromised by any of the restoration/conservation works.

Accordingly, an independent architect was appointed, by English Heritage, to oversee the various items of work, and represent their views on site.

During the architect's initial visit to the site, serious concerns were raised about the tying of the arches. The installation of the ties had been carried out prior to the architect's appointment, and it was pointed out that the ties were a contravention of the original 'listing' of the building. The architect considered the ties to be detrimental to the general ambience of spaciousness within the Hall, and may have impinged on the 'listing' criteria.

A request was made for the ties to be removed forthwith, and the structure returned to its original state.

However, when the tenuous nature of the structure was pointed out to the architect, the decision was taken to seek the opinion of an independent engineer, in order to resolve this early conflict of interests. The English Heritage engineer reviewed the design analysis, and agreed with the views expressed by the City's structural engineer. The need to hold the structure against further movement was accepted, as was also the installation of the metal tie bars.

However, the English Heritage engineer put forward an alternative proposition; he suggested that the tying of the two diagonal arches, across the intersection of the aisles, may not be necessary. (These particular ties had not been fixed in position at this time - although the anchoring brackets for the ties were already fitted to the arches). The engineer's argument was that the ties already fixed to the shorter span arches formed a "square" of ties, around the intersection area, and should be sufficient to hold the springing points of the larger arches in position.

This opinion was countered by the Town Hall structural engineers, because the greatest movement had been recorded at the base of one of the diagonal arches, but as the Council did not wish to appear unco-operative, a compromise suggestion was agreed upon. The compromise proposal was to undertake a monitoring of the larger span arches, over a specific period of time; to assess if any significant movement was taking place. After a twelve month period no adverse movements had been detected at the cap level of the four square columns; it was therefore conceded that the diagonal ties could be dispensed with, and would not be fitted across the intersection of the aisles.

A similar complaint was raised, by the English Heritage architect, regarding the restraining ties fitted across the apex points of the side aisle trusses, with a request for their removal; but, the visual evidence of the buckled rafters, and the independent engineer's agreement to the installation of the ties, quickly negated any further action over this particular complaint.

Figure No. 6 Depicts the various parties involved in the restoration/conversion of the City Hall, and indicates the manner in which each party leaned or pulled towards their own agenda.

At the outset of the restoration proposals, the City Architect assigned two of his most experienced staff architects to undertake the task of overseeing the restoration works and co-ordinating the design of any conversion works required to meet the needs of the Air and Space Museum.

As work commenced on the site discussions were held between the English Heritage architect and the City Architect's representatives, to determine the nature and extent of the restoration work. It was at this point that further conflicts of interest became apparent and needed to be properly resolved before the works progressed too far.

One significant problem arose from the inability of the wrought iron arches to accept any additional loadings. In order to meet the present day statutory requirements, the structural engineer had found it necessary to impose a loading limit on the arches, which precluded the use of heavy natural slate from being used as a roofing material. Some lighter cladding material would have to be utilised as a substitute.

The English Heritage architect was insisting that the restoration works must be as the 'status-quo', ie. the roof must be restored as originally constructed. The Town Hall architects maintained that this was not possible, and a compromise was essential to move the works forward. Eventually, the issue was resolved by adopting mineral fibre slates, which were half the weight of natural slates, and would still provide an acceptable slate type finish to the roof. The loading imposition was also contentious to the Air and Space design team, who had assumed that they would be able to suspend a number of their exhibits from the roof supporting beams and arches. However, under the imposition, heavy exhibits were prohibited, but smaller, lighter items, such as kites and 'hang gliders' were considered to be acceptable.

A second major problem materialised when the Air and Space team accepted the offer of a Shackleton, four engined, aeroplane from the Ministry of Defence (via arrangements with the Director of the RAF Museum). This huge aircraft, with a wing span of 119ft (36.5m), had to be brought into the building and manoeuvred into a salient spot. Getting the aircraft into the existing structure would be the problem. Originally, a large entrance door was located in the south gable wall, sited at the central position of the cross aisle. The entrance gave access for pantechnicons to deliver large display items for exhibition purposes. Sadly, the existing entranceway was of insufficient size to accomodate the four engined aeroplane. The Council's architects were faced with no other alternative but to increase the size of the opening; and this is where the conflict arose.

The architects and the Air and Space team wanted to leave the enlarged entrance as a feature - to facilitate the removal and acceptance of the larger aircraft for display. The idea was to provide a demountable glazed frontage, which could be readily removed, and would also allow the passers-by to view the exhibits inside the museum.

The English Heritage architect rejected these proposed changes to the original Victorian facade; only agreeing to a compromise, whereby the features of the original facade would be rebuilt and retained, but the lower level would be infilled with clear glazing, instead of brickwork, and the wrought iron railings would not be replaced across the opening.

Other areas of minor conflicts emerged as the works progressed, mainly regarding the cast iron embellishments around the building, some of which had broken, cracked or simply disappeared. These defective embellishments were eventually made good, except for three or four of the larger ornate cast iron brackets, which supported the lattice girders across the end gables of the aisles. It was contended, by the iron founder responsible for re-making the defective embellishments, these large brackets were of such an intricate nature that it would not be

possible to accurately reproduce the patterns without removing one of the remaining brackets from the building. This was not considered to be a viable option, and the existing 'modern' brackets were, therefore, not replaced. (See photos Nos. 1 to 4) The pursuit of the various conflicts of interest tended to retard the progress of the work on site, until they were properly resolved, and so created problems for the Main Contractor, who found it difficult at times to maintain a steady flow of site work for his workforce. However, every effort was made to meet the target deadline in 1983, and this was, happily, achieved.

Setting-up the Air and Space Museum

Following its decision, in 1980, to re-vamp the City Hall building and create an Air and Space Museum, the City Council took a further move forward by setting up a special Trustee Committee, under the Chairmanship of Councillor Norman Morris; with other politicians and senior Council officers making up the committee. The Director of the RAF museum at Hendon was also included as an 'ex-officio' member of the committee.

The Trustee Committee was the driving force behind the new venture; being the decision making body which would oversee all the financial and legal aspects of the project. The committee quickly set the date for the opening of the Air and Space Museum as Easter 1983; and every effort was to be made to ensure that this target date would be achieved.

Figure No.7 depicts the interaction between the Trustee Committee and the Design Teams.

Two separate design teams were employed to create the new museum, and were drawn from independent sources. One was formed from the staff of the Royal Air Force Museum at Hendon, under the direction and control of the Director. This team concentrated on the types of aircraft that would be made available as exhibits, and also set down the proposed location and positioning of each aircraft within the display gallery; together with the arrangement of pathways, to be followed by the public, through the museum.

The second team was composed of the architectural staff assigned by the City Architect for the restoration works on the old hall. The team's task was to co-ordinate with the RAF design team to ensure that all the conversion works were feasible and compatible with the general ambience of the building, while also complying with the current statutory regulations. The team was also responsible for liaising with the English Heritage architect to make sure that none of the conversion works compromised the 'listing' of the building in any way.

At the end of 1981 the Ministry of Defence, through the Director of the RAF museum, made it known that a Shackleton four engined aeroplane was due to be de-commissioned during 1982, and could be made available as an exhibit in the new museum at Manchester.

The problems associated with huge aircraft have been outlined earlier, but it is worth recording that, in order to bring the Shackleton into the building, it had to have each of its wings dismantled - back to their intersection with the two in-board engines. This reduced the 119ft(36.5m) overall wing span down to a manageable 46ft(14m); which was just sufficient to allow the plane to pass through the specially enlarged opening in the south gable.

Although the allocation of the Shackleton to the museum was good news, the conversion process did not run too smoothly for the Trustee Committee. In the Spring of 1982, it was considered that the Ministry of Defence, and the administrator at Hendon, were "dragging their feet" over a number of legal and financial agreements relating to the leasing of some of the aircraft to be displayed.

The Trustee Committee were so perturbed, by the procrastinations, that it felt the whole museum project could be in jeopardy and recommended to the City Council that the conversion works should be put on hold until the situation could be clarified. The restoration work was to continue, but no further work was to be undertaken on the museum project.

Fortunately, the problems were resolved by the summer of 1982, and the conversion work was allowed to continue.

At about this time the Trustee Committee decided to appoint a Director/Curator for the Air and Space Museum, who would be able to take over the responsibility for the day-to-day management, organisation and running of the museum with immediate effect. Suitable applicants were interviewed for the post, and the Directorship was finally awarded to Peter Baston, a former curator with the North-west Museum of Science and Industry at Grosvenor Street.

Throughout the latter part of 1982 there was a flurry of activity as the conversion works were carried on at a pace. Under Mr. Baston's direction the exhibition aircraft started to arrive and take up their appointed positions in the gallery. However, the Ministry of Defence again delayed matters by not de-commissioning the Shackleton until the end of November 1982; thus creating a 'knock-on' effect with the progress of the restoration and conversion works. The Shackleton aircraft was finally delivered to the museum (in bits and pieces) at the turn of the year.

This unexpected delay caused the Main Contractor, John Laing, to be placed under intense pressure to complete their part of the restoration works within the target time.

With less than three months to the opening date, after the Shackleton had arrived, the contractor was faced with the task of re-forming and making good the enlarged entranceway, (to the satisfaction of both the English Heritage and the City Architect's representatives) plus the rebuilding of that portion of the balcony which had been removed in order to provide adequate access to the enlarged entranceway. This was no easy task, when all these works had to be undertaken at the same time, and in the same location, as the team of RAF fitters worked on the re-assembly of the Shackleton.

However, after almost six years of controversy, conflicts and administration uncertainties, the restoration and conversion works were finalised within the target time. All the aircraft were in their allotted positions, and the Shackleton was ready to be displayed as the Museum's "pièce de résistance". The Manchester Air and Space Museum was officially opened on Tuesday 29th April 1983.

The Sting at the End of the Tale

Like all good stories, the Air and Space Museum saga has a sting at the end of the tale.

In the Spring of 1984, just twelve months after the official opening of the Museum, one of the major sponsors withdrew their financial support for the project.

This left the City Council facing an immediate deficit of around £50,000 towards the administration of the museum. The Council had no alternative but to

accept the situation, and seek out another sponsor. This was not easy, and, after six months, the City Council requested the Finance Sub-Committee and the Museum Trustee Committee to review the situation, and put forward proposals for the future funding of the museum.

By the end of 1984, the only viable option was to offer the new Air and Space Museum to the Greater Manchester Council, to be taken into, and become part of, the larger Museum of Science and Industry.

So, after spending over £2 million on restoration and conversion works, the City Council simply handed everything over to the Greater Manchester Council during December 1985.

Author's Footnote

This fine, 19th Century, Victorian building, with its fascinating historical structure, pre-dates all of the exhibits on display in the museum; and could continue to give service to the general public well into the 22nd Century.

Hubert Dickson CEng. FISTructE.MAE.

APPENDIX

CONTENTS:

- 1 FIGURES Nos.1 to 7
- 2 PHOTOGRAPHS Nos.1 to 4
- 3 CHRONOLOGY OF EVENTS
- 4 ACKNOWLEDGEMENTS

Fig (1)

UPPER & LOWER CAMPFIELD MARKETS
MANCHESTER - 1878

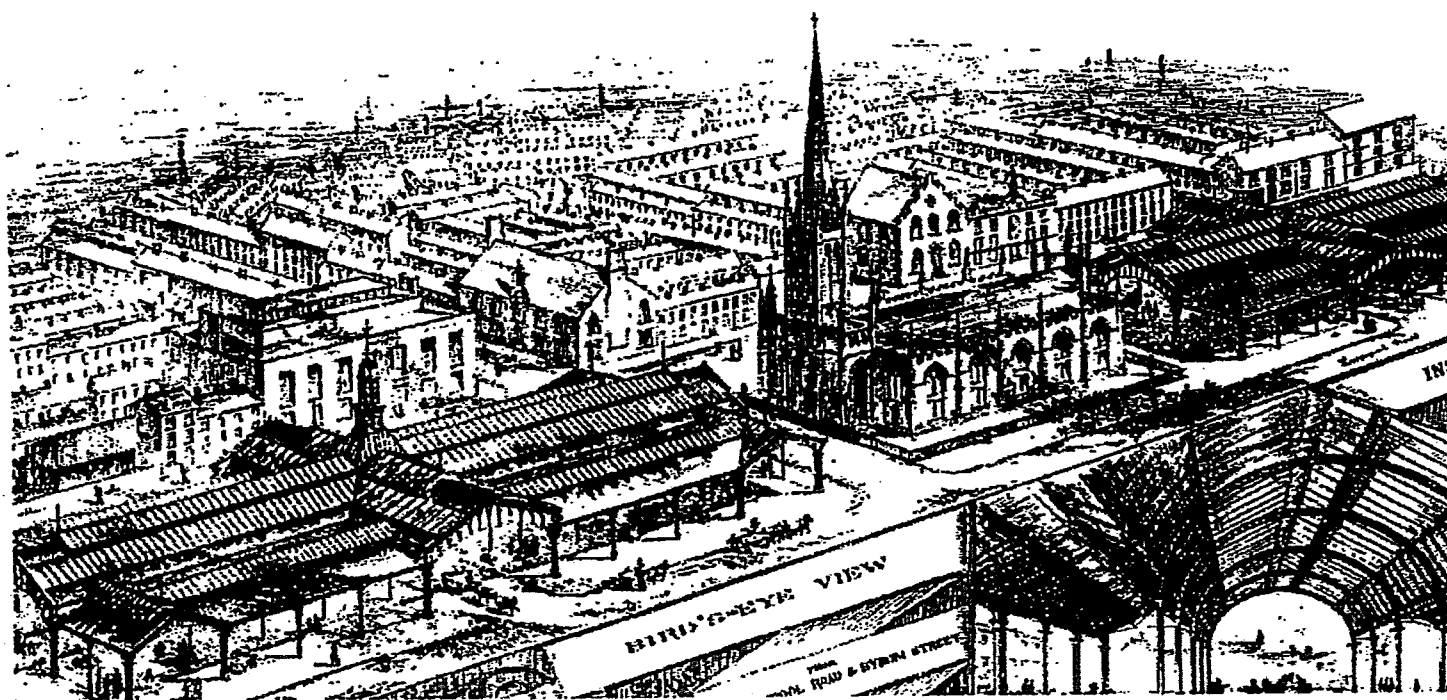
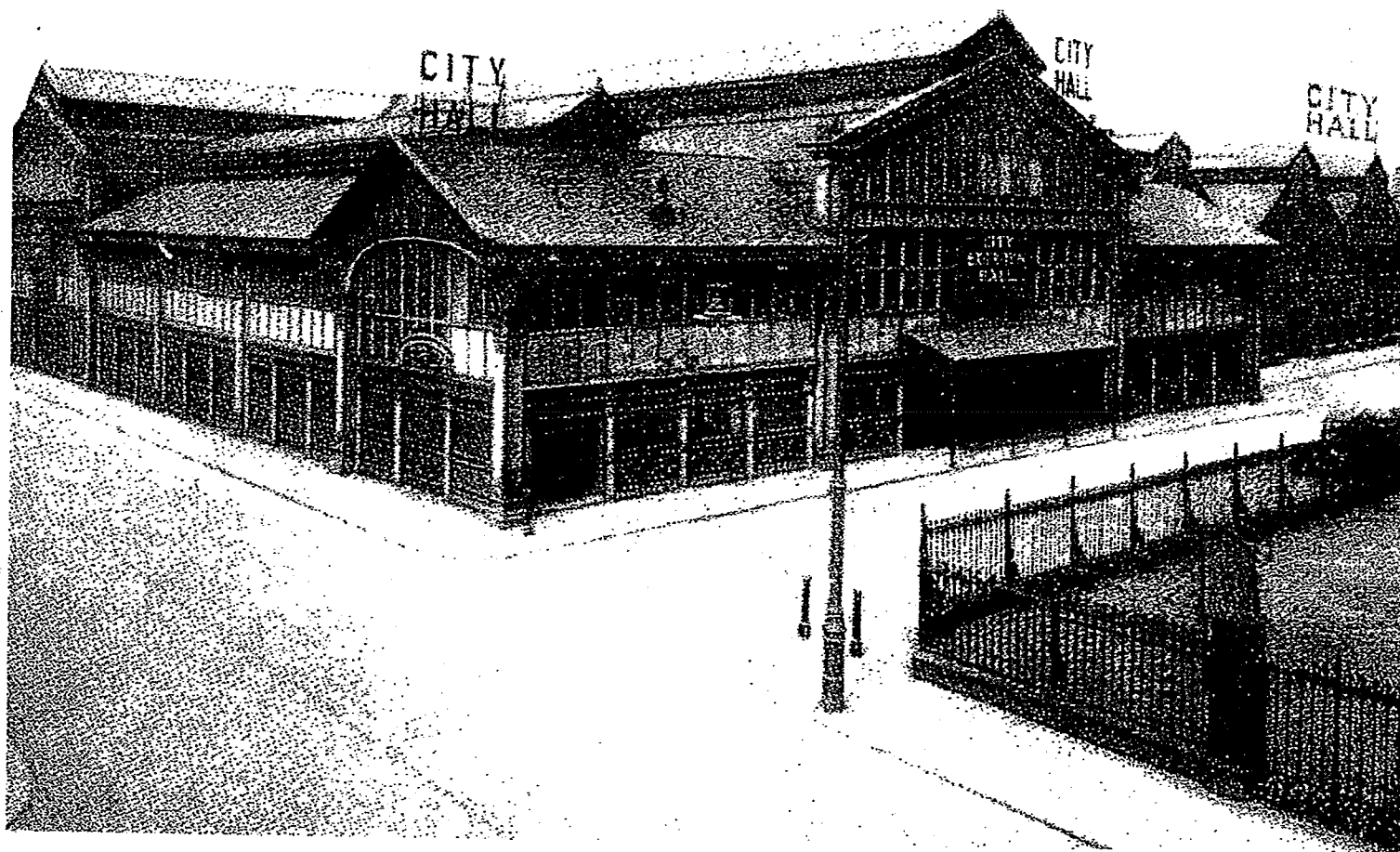


Fig (2)

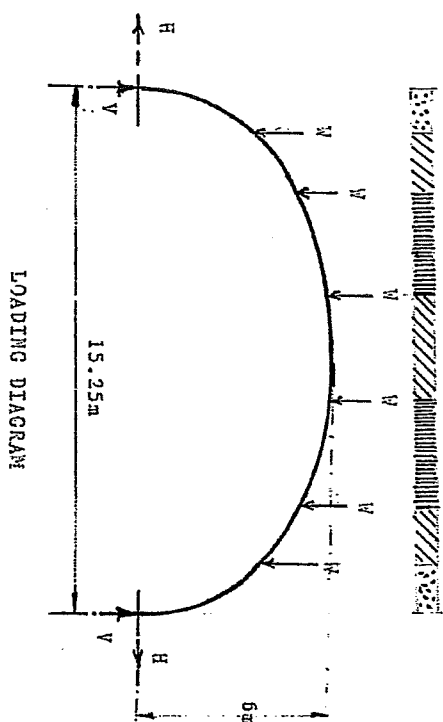
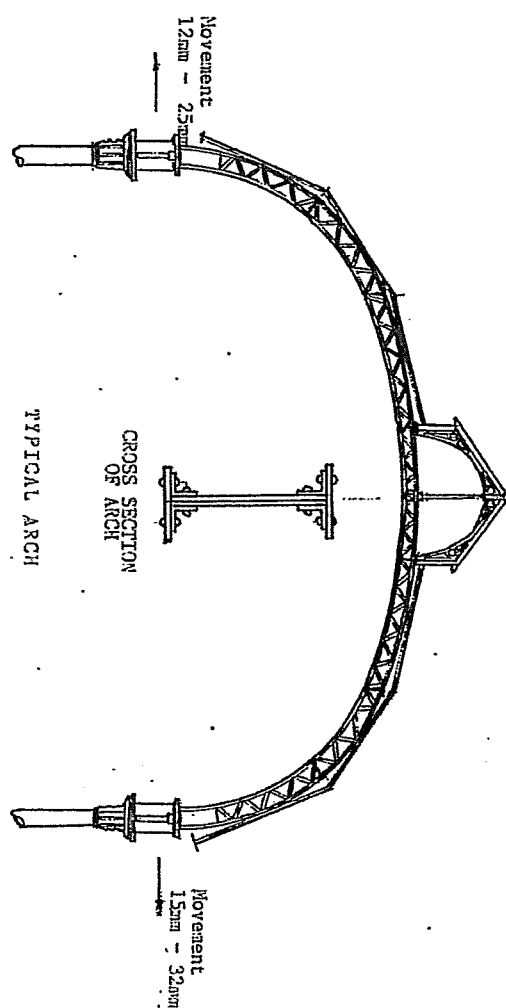


Fig ③



ANALYSIS of the ARCH

Fig ④

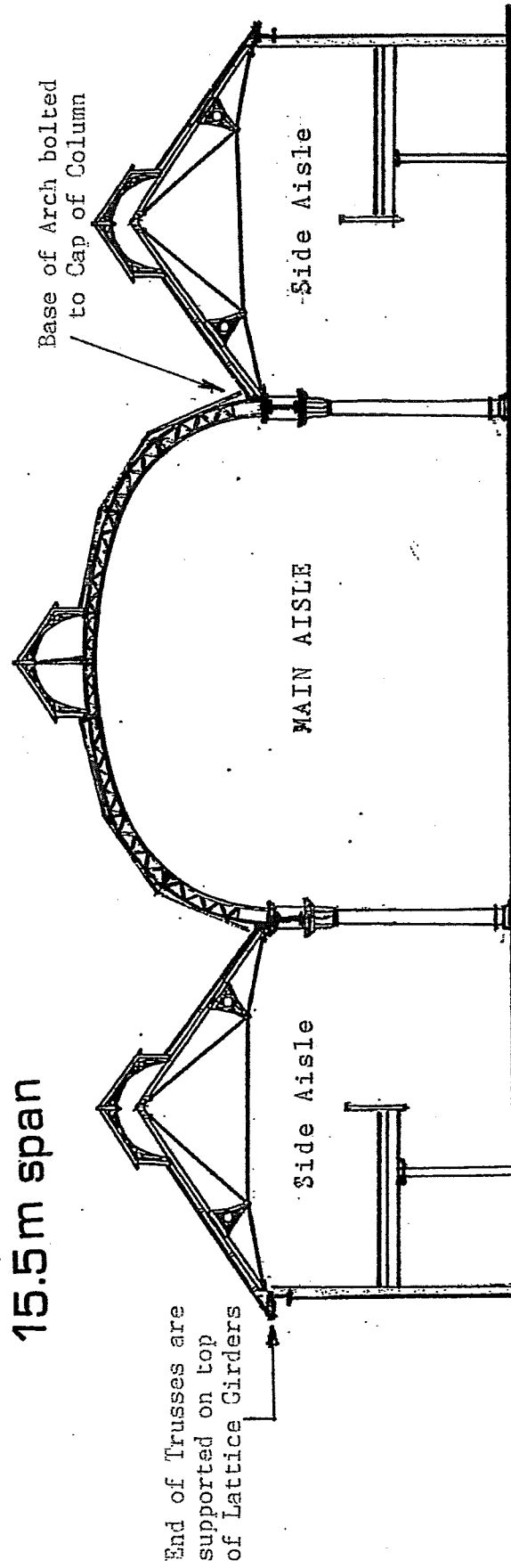


Variations in Superimposed Loadings

- ▨ 0° - 30° Intense 15 lbs/sq.ft
- ▧ 30° - 35° Moderate 13 lbs/sq.ft
- ▩ 60° - 67° Nominal 3 lbs/sq.ft

Fig 5

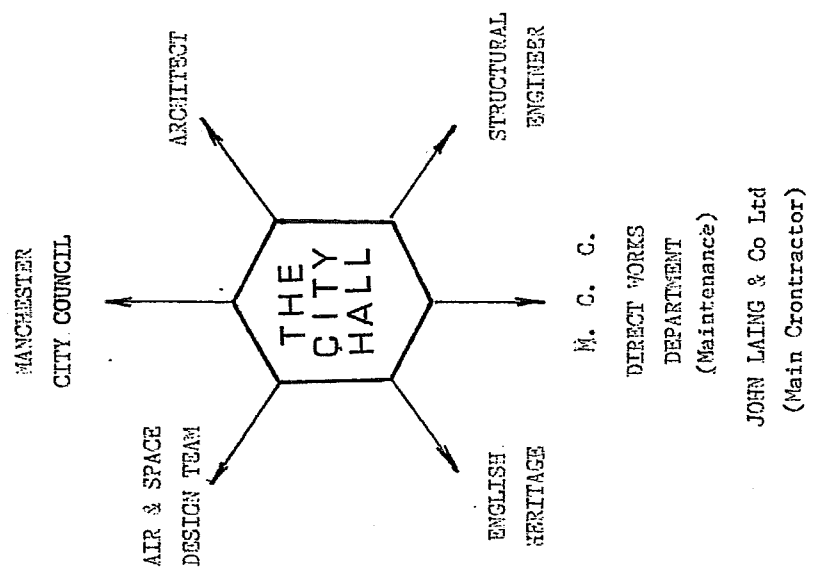
City Hall
15.5m span



TYPICAL CROSS SECTION

Fig 6

CONFLICT OF INTERESTS

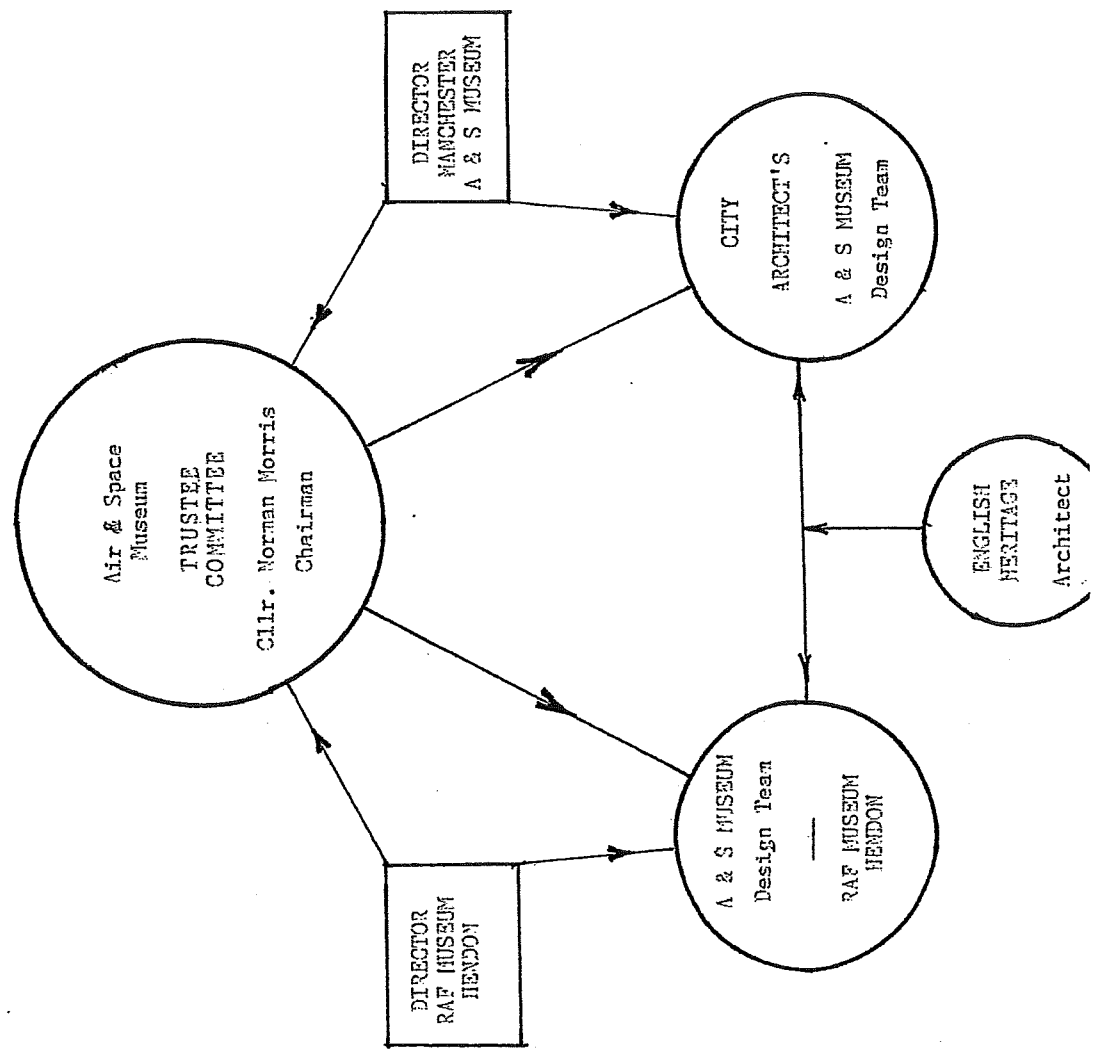


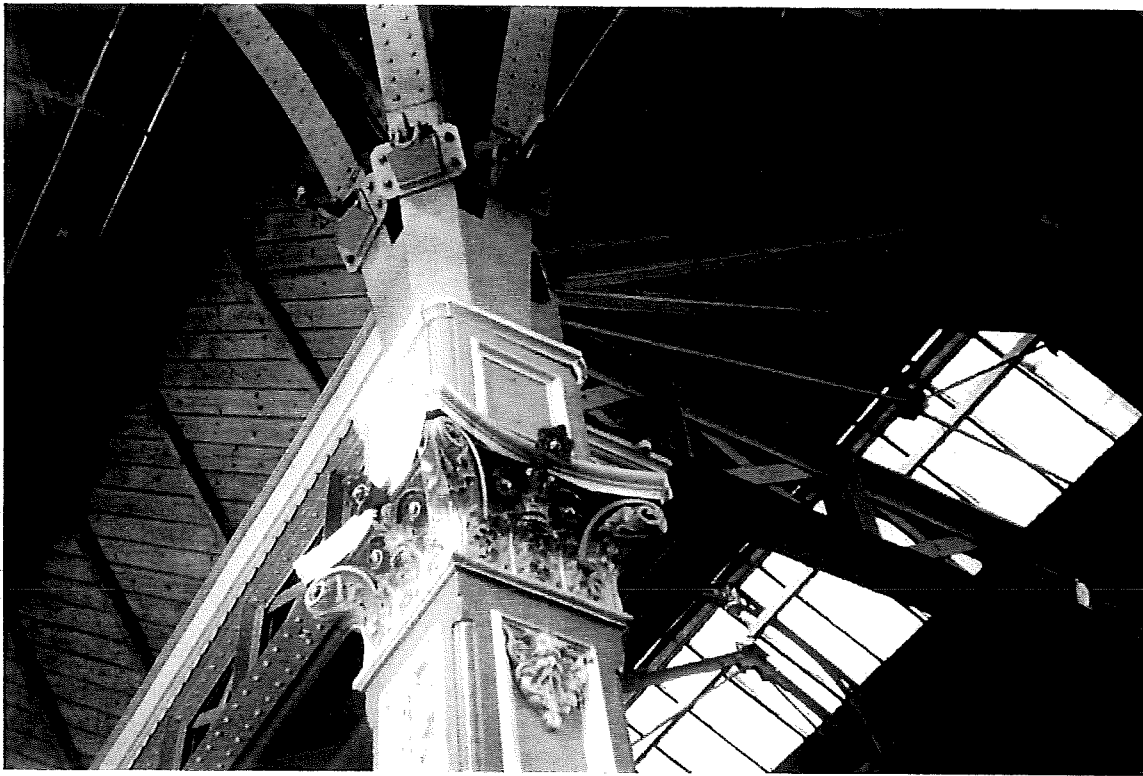
MANCHESTER AIR & SPACE MUSEUM

Fig 7

ADMINISTRATION - DESIGN - DIRECTORATE

INTERACTIVE MODEL





1

Corinthian Capital on a Square Column
Note the bases of three arches springing from
the column, with the tie bars and brackets.



2

View of Corinthian Capital on
Circular Column.

Note the WI Lattice Girders
and base of the arch resting
on the column, with the tie
bar and bracket in position.



3

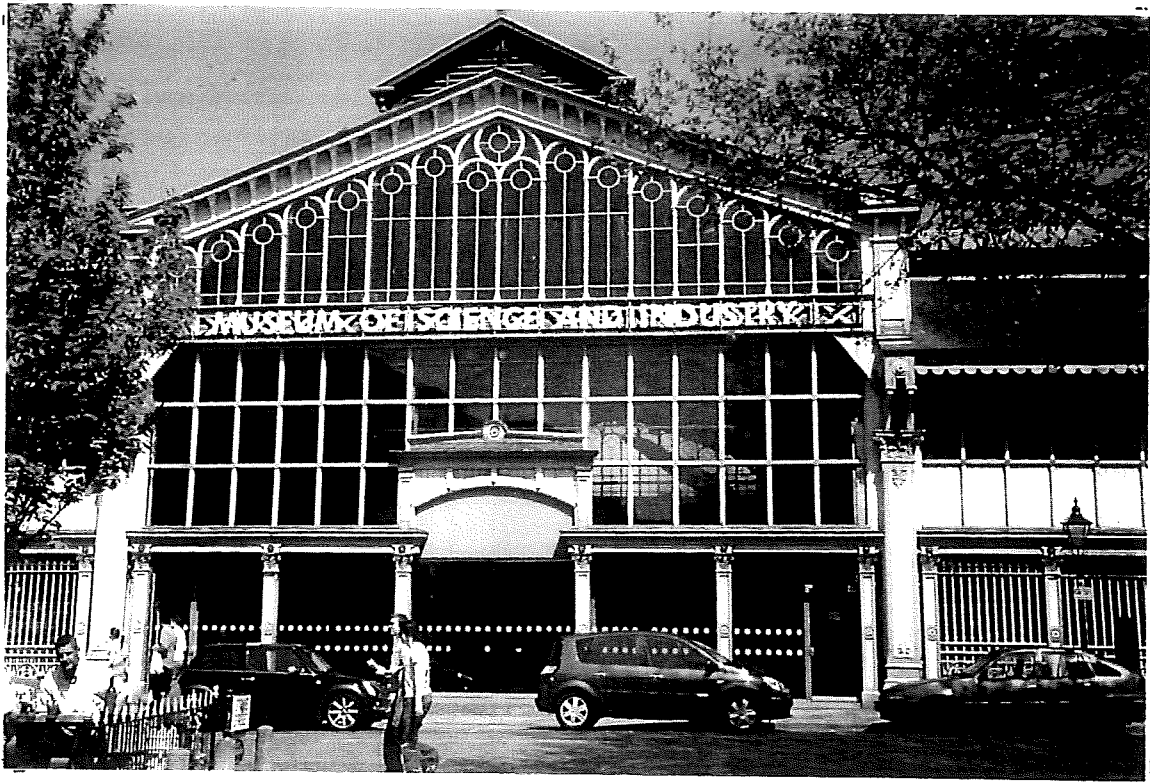
View of an ornate cast iron bracket supporting the Eastern Gable WI Lattice Girder.



4

Fabricated welded mild steel bracket on the Western Gable as a substitute for the original ornate cast iron supporting bracket.

VIEWS of the MUSEUM - 2006



5

View of South Gable

With the 'Historical Railings' replaced by full height clear glazing.



6

External Columns.
Showing the 'rose'
embellishments and
'Historical Railings'.

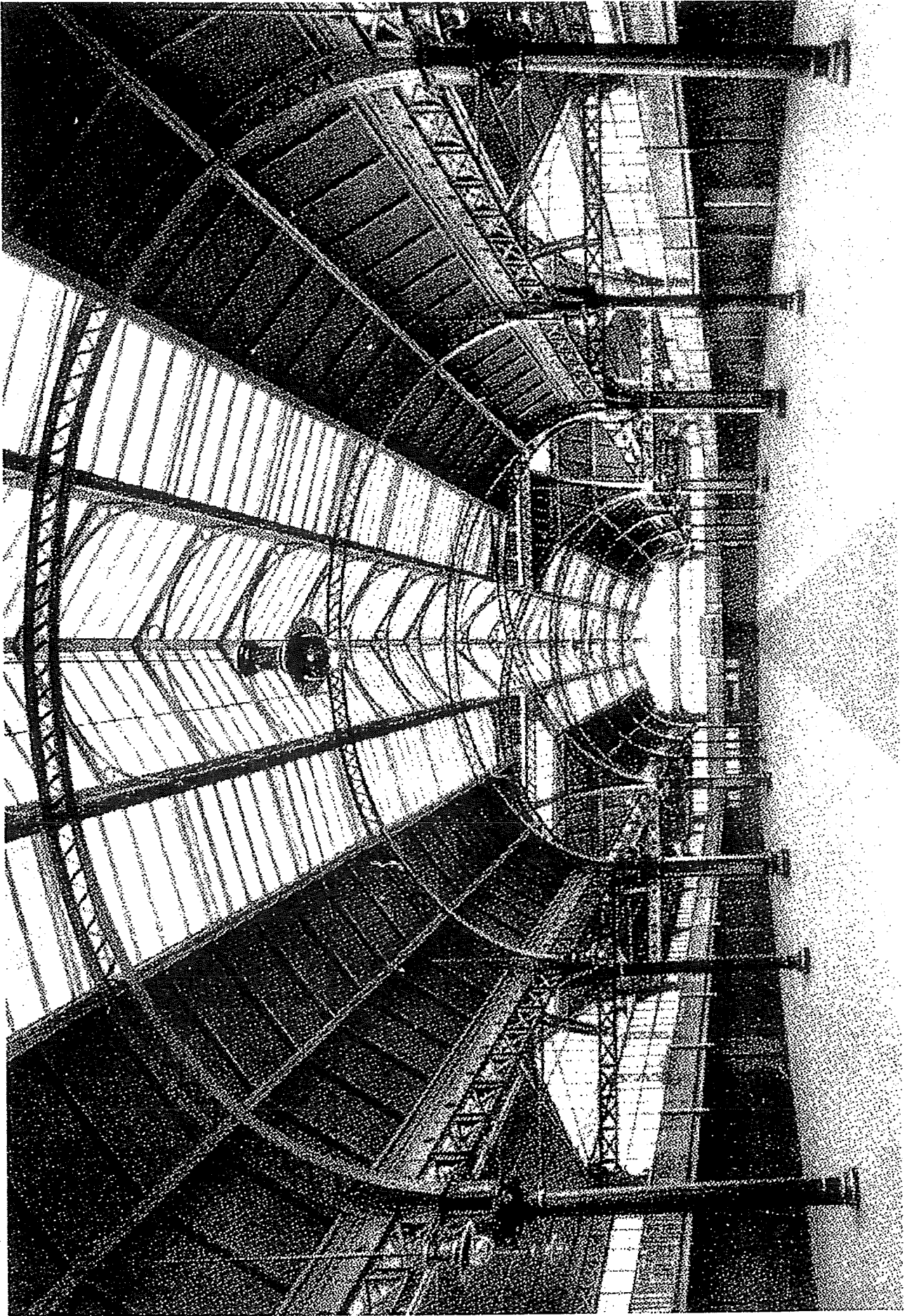
CHRONOLOGY of EVENTS

- 1875 Mangnall and Littlewood, Architects, commissioned to design Market Halls in Campfield, Manchester.
- 1878-80 The Upper and Lower Campfield Market Halls are opened.
- 1900 Lower Campfield Market Hall is closed for re-development by Manchester City Council as the City Hall - Exhibition Centre.
- 1902 City Hall is opened, with building completely enclosed.
- 1910 The balcony, around the periphery of the City Hall, is enlarged.
- 1939 City Hall is closed at the outbreak of World War II.
- 1940-45 City Hall is used for " war work", ie. making barrage balloons etc.
- 1946 City Hall re-opens, to the public, as an Exhibition Centre.
- 1974 The City Hall becomes a Grade II Listed Building.
- 1977 City Hall is closed due to fire damage at the eastern end of the building.
- 1979 Manchester City Council decide to convert the City Hall for use as an Air and Space Museum.
- 1980 Maintenance work is commenced which involves tying the arches and improving the drainage.
- 1981 Major restoration works commence on the infra-structure of the City Hall, with the upgrading of the cast ironworks and re-fitting work, internally and externally, to produce the Air and Space Museum.
- 1983 The new Air and Space Museum is opened.
- 1985 The Air and Space Museum is handed over, by the City Council, to become a part of the Manchester Museum of Science and Industry; and has remained a specialised gallery of the Museum for the passed 20 years.

ACKNOWLEDGEMENTS

Acknowledgements and thanks are owed to the following Bodies, organisations and individuals; without whose generous help and guidance, I would not have been able to present this paper.

- 1 Museum of Science and Industry. Manchester
- 2 Manchester Central Reference Library.
- 3 English Heritage.
- 4 Manchester Evening News.
- 5 Institution of Structural Engineers.
- 6 Rev. Dr. Richard Hills MA. DIC. CIMEchE.
- 7 Robert Atkinson CEng. MICE. MIMStructE.
- 8 Peter Batson.
- 9 David Hilton. Manchester City Council.



C. M. Moncreuff
68/7/92

WROUGHT IRON

BRIDGES AND ROOFS.

LECTURES DELIVERED AT THE ROYAL ENGINEER
ESTABLISHMENT, CHATHAM.

WITH EXAMPLES OF THE CALCULATION OF STRESS IN GIRDERS AND
ROOF TRUSSES BY GRAPHIC AND ALGEBRAIC METHODS.

BY
W. CAWTHORNE UNWIN, B. Sc.
ASSOCIATE INST. C. E.

London:
E. & F. N. SPON, 48, CHARING CROSS.
1869.

All rights reserved.

① The arched roof differs from the arched bridge in this, that whilst in the latter case we can easily accumulate in the abutments any amount of resistance to horizontal thrust, in the case of the roof, springing from the summit of lofty walls or pillars, horizontal resistance is very difficult to obtain.

② *Arched roofs*, in which the rigidity of the curved rafter is sufficient to resist the distorting influence of the load without additional bracing. Such roofs may or may not have a tie rod, but their proportions are to be determined on the principles applicable to the iron or elastic arch.

③ It can be further assumed that the weight of a cubic foot of snow varies from $5\frac{1}{2}$ to 11 lbs., according to the amount of consolidation, so that an allowance of 5 lbs. per square foot of *horizontal* surface covered by the roof is ample.

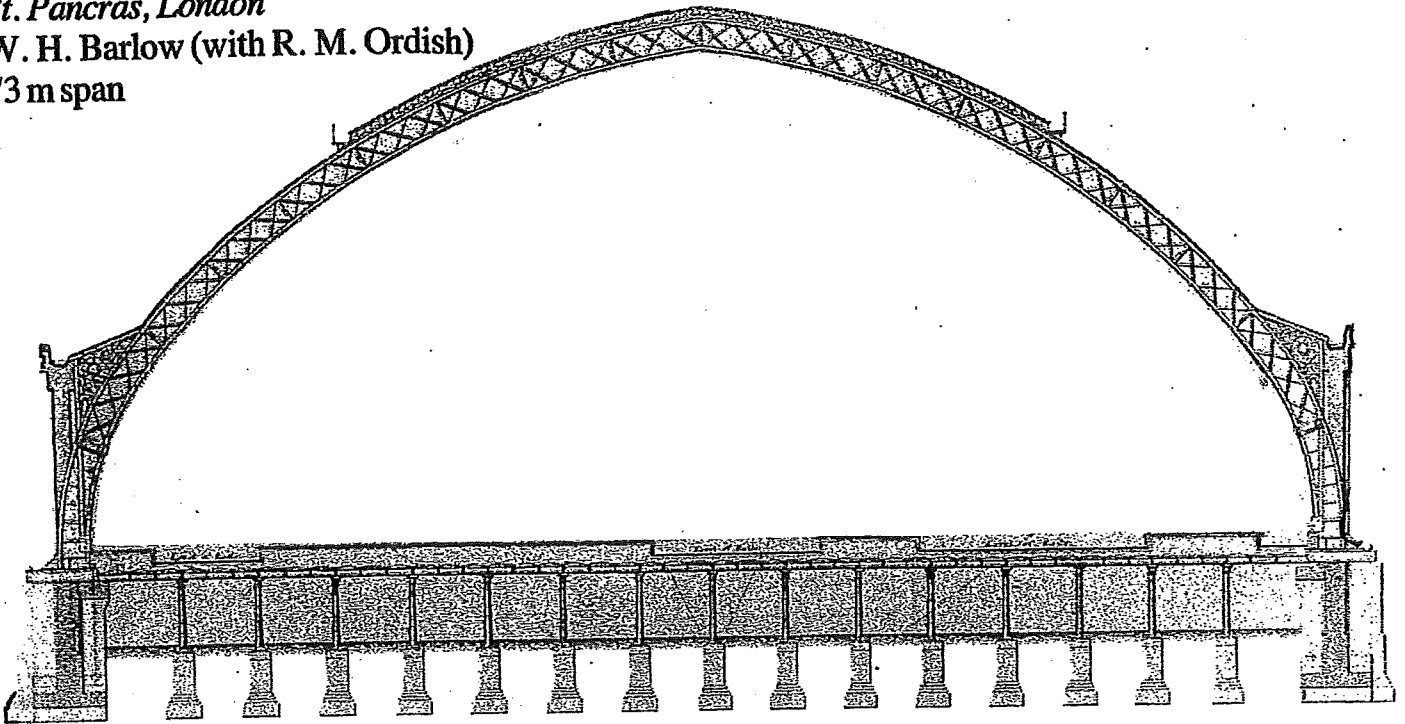
COMPARISON OF ARCHES

1868

St. Pancras, London

W. H. Barlow (with R. M. Ordish)

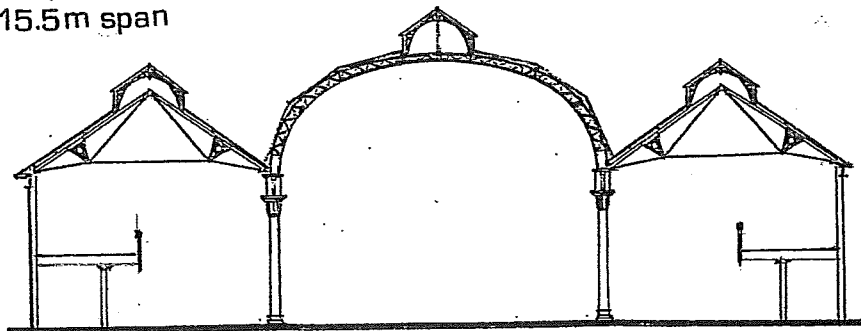
73 m span



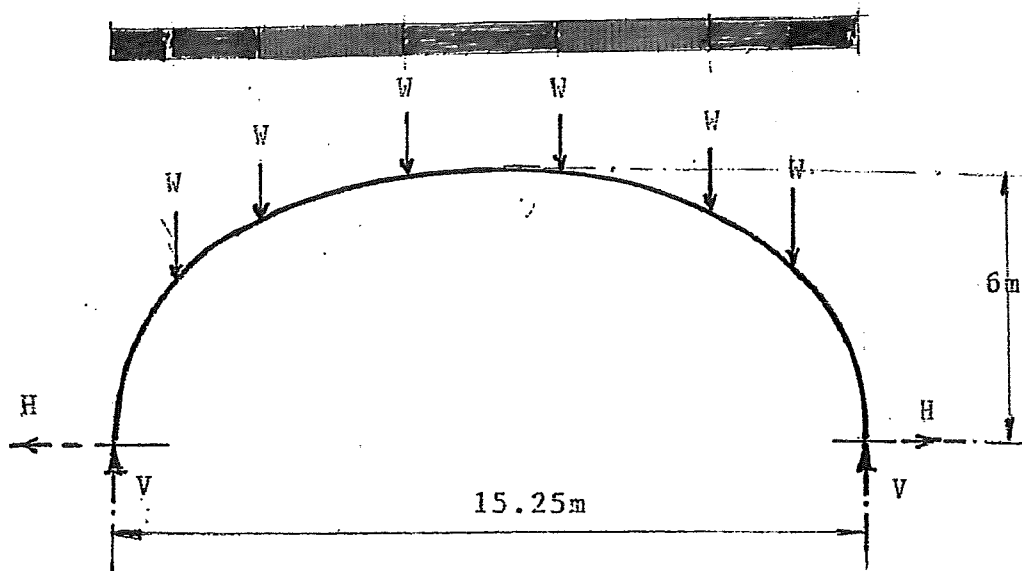
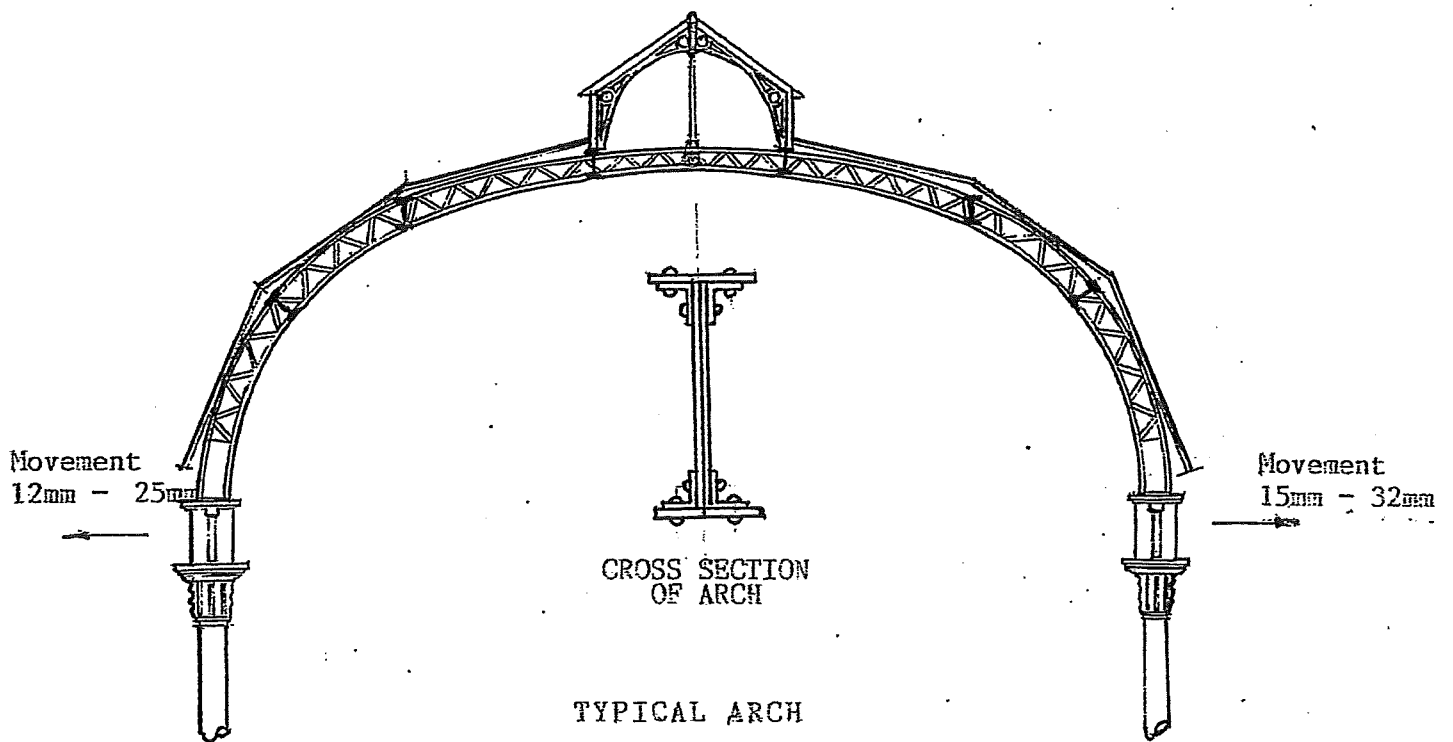
1878

City Hall

15.5m span



ANALYSIS of the ARCH



LOADING DIAGRAM

Variations in Superimposed Loadings

	0° - 30° Intense 15 lbs/sq.ft
	30° - 35° Moderate 13 lbs/sq.ft
	60° - 67° Nominal 3 lbs/sq.ft